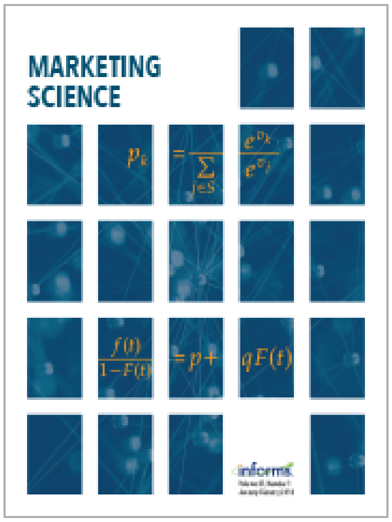

Marketing Science

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

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MARKETING SCIENCE
Vol. 24, No. 3, Summer 2005, pp. 396–414
ISSN 0732-2399 | EISSN 1526-548X | 05 | 2403 | 0396

DOI 10.1287/mksc.1040.0105

Collaborative Product and Market Development: Theoretical Implications and Experimental Evidence

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In alliances jointly developing product and market, we first investigate how (a) the number of networks competing to develop a product, (b) the number of alternative technology platforms, and (c) market sensitivity to product development expenditures affect investments of partnering firms. We find that, in equilibrium, when the number of either competing networks or technologies increases, investments are more likely to be directed toward market, rather than product, development. Second, we consider the case in which firms continue to jointly develop a product but compete individually in the market. Our analysis suggests that forcing alliance partners to compete individually might not attenuate the underinvestment problem associated with new product alliances. Third, we extend the model to consider sequential market entry with rewards based on the order of entry, technology spillover, endogenous market size, and asymmetric technologies. Finally, key predictions of the basic model are tested in two experiments. The aggregate results provide strong support to the qualitative implications of the equilibrium solution but only mixed support to its quantitative predictions.

Key words: new product research; alliances; experimental economics; game theory; two-stage competition
History: This paper was received February 19, 2004, and was with the authors 1 month for 1 revision; processed by Robert J. Meyer.

1. Introduction

1.1. Motivation for the Research

In a survey of Fortune 1000 firms conducted 20 years ago, it was found that a third of the profits to be earned in the next 5 years would come from new products (Booz et al. 1982). This percentage has been steadily growing, particularly in the high-technology industries. Increasingly, firms rely on alliances rather than internal processes to develop and market these products (Rindfleisch and Moorman 2001, Sivadas and Dwyer 2000). Because no more than 50 percent of new products are successful and the base success rate of alliances in general is no better, new product alliances are prone to failure (Zirger and Maidique 1990, Park and Ungson 2001). Recognizing the managerial significance of new product alliances, academic researchers have studied the antecedents, processes, and consequences of new product alliances (see Rindfliesh and Moorman 2003 for a recent review).

A central feature of many new product alliances is that they are often marked by two distinct phases of potential contribution: product or technology development and market development. In some cases an alliance covers both phases of development. For example, DowCorning and NeoPhotonics have formed an alliance to jointly develop and market the next generation photonic crystal technology (*Thomson Financial*, June 5, 2002), and Toshiba and Sandisk are proposing to jointly develop and market sophisticated flash memory chips (*Thomson Financial*, October 9, 2002). In other cases, the alliance might hold for only one phase of development, such as product development. For example, IBM and Intel propose to jointly develop a line of servers but independently market it (*Thomson Financial*, Sept. 17, 2002).

1.2. Overview

The purpose of this paper is modest. We attempt to study both theoretically and experimentally how the structure of competition affects the resources committed by alliance partners to product and market development. Given the complexity and multidimensionality of collaborative product and market development, we limit our investigation by focusing on only two structural features of the competition, namely, the number of competing networks and the number of available technologies. We formulate a stylized two-stage model of internetwork competition and examine its implications for equilibrium investments in product and market development. Our investigation attempts to offer some insight on three questions about collaborative product and market development.

1. *How does an increase in the number of competing networks or technologies affect collaborative development*? It is convenient to hold the view that joint investments in product development should increase as more networks compete to develop a technology because competition is supposed to encourage aggressive investment. Furthermore, if joint investments in product development increase in the number of competing networks, it is not clear whether it would dampen investment in market development. Likewise, multiplicity of technology platforms might increase competitive investments in both product and market development. On the other hand, an increase in viable technology platforms could potentially depress competitive investments, because there is less to be gained from increased competition. Our analysis shows that as the number of competing networks increases, equilibrium investments in market development grow while those in product development decline. Similarly, an increase in the number of alternative technologies decreases investments in product development but increases investments in market development. These results have important practical implications. They suggest that as competition increases, investments are likely to be directed more toward the market than the product. Thus, competition could shape the orientation of a firm toward product and market development.

2. *What is the effect of individually, rather than jointly, developing the market*? Some argue that forcing partners who jointly develop a product to compete separately in the market might actually attenuate under-investment problems associated with joint product development (see Cohen 1994). We find that individual development increases investments in market but decreases investments in product development. Thus, forcing each partnering firm to market an innovation independently might not reduce the under-investment associated with joint product development.

3. *Does our theory account for the investment behavior of economic agents*? Using a repeated-trial-between-subject design, we conducted two experiments that implemented the assumptions of our model of same-function alliances (joint development of product and market) and its extension to individual development of markets. These two experiments focused on testing the predictive accuracy of the model, not the validity of its assumptions. Furthermore, we used business school students rather than alliance managers as subjects. The results of our two experiments suggest that the aggregate behavior of financially motivated individuals is directionally consistent with the model predictions. These findings need to be replicated and further corroborated with field data.

1.3. Related Literature

Our work is related to the literature on strategic alliances in economics, marketing, and management. The economics of research joint ventures is an active field of research in industrial economics (e.g., Kamien et al. 1992, Kamien and Zang 1993, Amir et al. 2003). The focus of this literature has been on performance evaluation of various forms of cooperative R&D relative to noncooperative R&D. The main result is that for industries with nearly symmetric firms full cooperation in R&D is good for all concerned. Our basic model also formulates the collaborative development of product and market as a two-stage game and maintains the assumption of symmetry of partnering firms mostly to gain tractability. However, it focuses on very different structural variables and institutional arrangements. The literature in management covers issues such as the stability of alliances, interpartner learning, alliance processes, and evolution of alliances and outcomes (see Gulati 1998, Mitchell et al. 2002 for an overview of the extensive literature in management). Marketing researchers have studied the antecedents to interfirm collaboration (e.g., Robertson and Gatignon 1998), determinants of success (e.g., Bucklin and Sengupta 1993), resource commitment of alliance partners (Amaldoss et al. 2000), new product related outcomes (e.g., Rindfleisch and Moorman 2001, Sivadas and Dwyer 2000), and implications of new product alliances for customer orientation (Rindfleisch and Moorman 2003). Our work adds to this body of literature in marketing by focusing on the temporal nature of alliance formation and examining its impact on product and market development. Our work is also related to research that examines how a firm's technology-related and market related capabilities affect its investments in new product development (Ofek and Sarvary 2003).

The rest of the paper is organized as follows. Section 2 motivates and outlines the assumptions that underlie our model formulation, proposes a two-stage model of joint development of product and market, and then discusses its implications. Section 3 presents and discusses the results of our experimental investigation. Section 4 points out limitations of the model and outlines directions for further research. Section 5 concludes the paper.

2. Theoretical Analysis

As real-world alliances may take multiple forms, there is tension between the desire to capture all the key elements of alliance formation and the need for a precise formulation of the process that would help in deriving testable predictions on the focal variables (see also Shugan 2002, p. 224). In our initial effort to model collaborative product and market development, we limit our focus to the examination of the effects of the number of competing networks and number of technologies on collaborative investments. Other important features of collaborative investments in product and market are either discussed briefly later in this section or relegated to future research. Below we discuss the assumptions that guide the model formulation.

Two-Stage Process

Our model formulation captures the spirit of a *sequential* development process. In the first stage, several networks compete to win a patent. In the second stage, alliances holding patents for the different technologies compete for a share of the market. We also explore the implications of independent market development. In our model, the alliances take their resource allocation decisions simultaneously. That is, we do not consider situations where a competing alliance can engage in product development after observing the actions of the first mover, as noted in the evolution of PDAs. Thus, our analysis is applicable to settings where an exogenous market need is simultaneously recognized by multiple firms who then compete to best satisfy it. We also do not consider parallel development of product and market by alliances (see Amaldoss et al. 2000).

Technological and Market Uncertainties

In the first phase of the collaboration, firms face technological uncertainties that are most common in high-technology industries. For instance, it is possible that the DowCorning-NeoPhotonics alliance, despite its efforts, might not succeed in developing a patentable photonic crystal technology. Likewise, in the second phase of collaboration firms could be confronted with unanticipated market behavior. We attempt to capture such uncertainties in our basic model by using a probabilistic contest success function in each of the two phases of collaboration, namely, product and market development. In this formulation, which is quite common in the rent-seeking literature (e.g., Tullock 1967, 1980; Nitzan 1994), investing more increases the probability of winning but by no means guarantees it.

Strategic Uncertainties

Network partners are, in general, not sure about the likely behavior of their partners as there is considerable scope for opportunistic behavior in these collaborations (Wathne and Heide 2000). In an attempt to capture the spirit of this uncertainty in our model, we assume that partners within a network make their decisions simultaneously in each stage. Consequently, partners cannot condition their behavior on the previous decisions of others.

Relative Importance of Investments in Product and Market Development

In some consumer product categories, investments in market development might be more crucial in determining the winner in the marketplace. In contrast, consider the collaborative endeavor of Toshiba and Fujitsu to develop and market a new chip (*Thomson Financial*, June 6, 2002). In cases such as this, investments in product development might have a stronger impact on market success. Our formulation allows for such possibilities.

Additive Utility Function

We assume that the value of the product developed by an alliance is determined by the *sum* of the investments of the partnering firms. Such a formulation is tenable where partners pool similar resources and their efforts are compensatory. For instance, in the above mentioned Toshiba-Fujitsu alliance, partners are pooling similar resources: both partners are pooling their knowledge of semiconductors and financial resources.

Winner-Takes-All

The basic model makes the simplifying assumption that the winner takes all. This assumption is a theoretical abstraction that reflects the essence of patent races and situations that facilitate the emergence of a dominant winner in some markets. In reality, we often see more than a single winner. Also in some markets, as reported in the pioneering advantage literature (e.g., Robinson and Fornell 1985, Boulding and Christen 2003), the profits that accrue to the winners are contingent on the order of their market entry. Later in this section we discuss the implication of allowing for multiple winners with the value of the market varying with the order of entry.

Composition of a Network

Firms in collaborative networks probably first decide whether to engage in a collaborative relationship, then they carefully choose their partners based on their resource base and reputation. Our model abstracts away from these key decisions. We assume that firms are symmetric within a network. Furthermore, the number of networks within a platform and number of technological paths are assumed to be exogenous variables. This structure helps us in focusing on the effect of these two variables on equilibrium behavior.

Technology Spillover

In high technology markets there is scope for technology to leak because of difficulties in patenting and movement of manpower (Griliches 1979, Jaffe 1986, Mansfield 1986). Our basic model assumes that there is no technology spillover. However, as we discuss later, this assumption is not critical for our model results.

Market Size

Another simplifying assumption is that there is a pre-existing market of a fixed size. In other words, we assume a fixed market that is not contingent on investments of the competing networks. This assumption facilitates the exposition of the key results (see Shugan 2004). It is quite likely that the market size is sensitive to investments in product and market development. We later show that relaxing this assumption does affect our theoretical results.

The Basic Model

Consider the case where T alternative technological paths are available to develop a product, and index these technologies by $i = \{1, 2, \ldots, T\}$. Each of these technological paths is pursued by N networks of firms. Index the networks by $j = \{1, 2, \ldots, N\}$. Each network comprises n partnering firms that we denote by $k = \{1, 2, \ldots, n\}$. Each firm is assumed to be endowed with a commonly known investment capital of y_{ijk}.

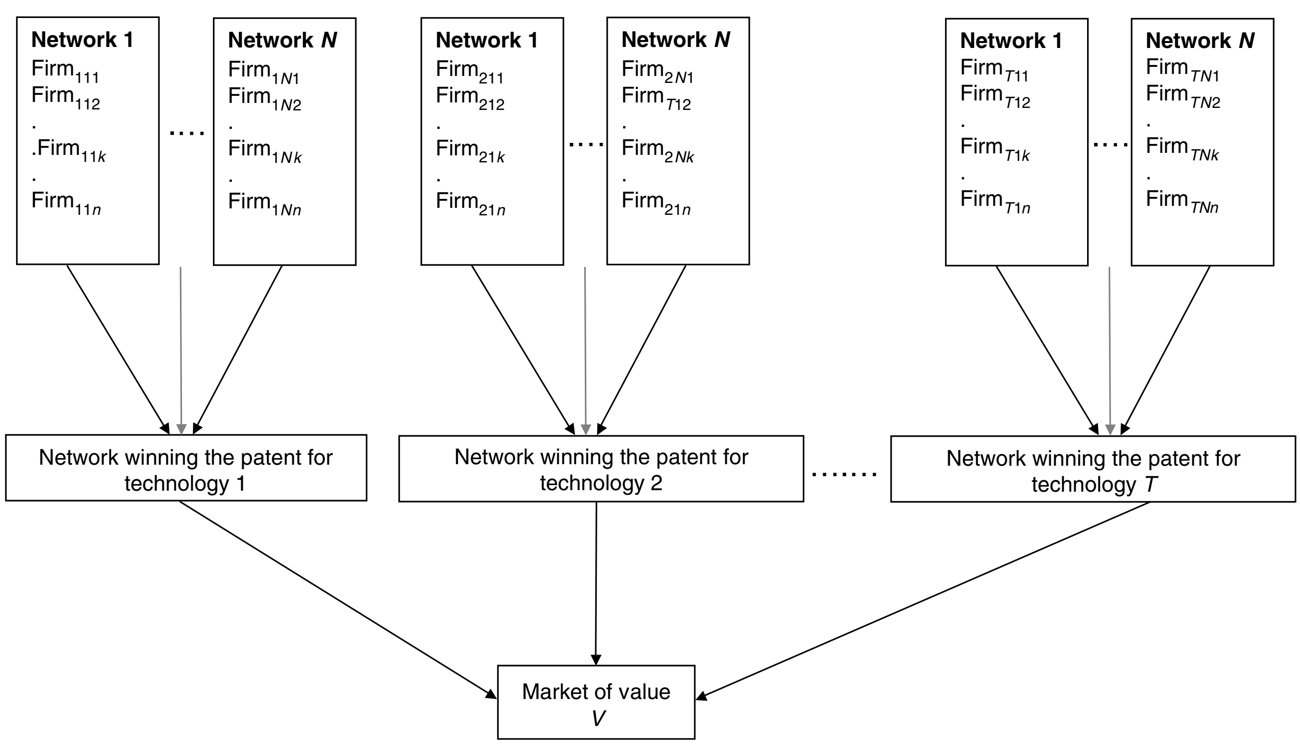
As illustrated in Figure 1, the product and market development game is assumed to unfold in two stages. In the *first stage*, networks (rather than individual firms) compete to develop a new product and win patent rights. Each firm invests some capital toward *jointly* developing the product of its network. The investments are translated into network-specific assets that have limited value beyond the scope of the alliance. For instance, these investments could be used to procure physical assets such as equipment and machinery or enhance human skills required for developing the new product (Williamson 1983). Consequently, investments are assumed to be *nonrecoverable*.

Let x_{1ijk} be the investment made in the first stage by firm k in network j pursuing technology path i $(0 \leq x_{1ijk} \leq y_{ijk})$. The joint investment made by network j in developing its product, which is based on technology path i, is $X_{1ij} = \sum_{k=1}^{n} x_{1ijk}$. Note that all partners in network j invest in only one technology (not multiple technologies). Following the extensive literature on rent-seeking (e.g., Tullock 1967, 1980; Nitzan 1994; Amegashie 1999), we assume that the winner of the product development competition is determined probabilistically. The probability of network j, which pursues technology path i, winning the product development stage is assumed to be proportional to the relative utility of its product:

$$p_{1ij} = \frac{U_{1ij}}{\sum_{m=1}^{N} U_{1im}}, \tag{1}$$

where U_{1ij} is the utility of the product developed by network j based on technology path i. The utility of a product, in turn, depends on how the resources are pooled in the network. As discussed earlier, we

Figure 1 Joint Product and Market Development



assume that $U_{1ij} = \sum_{k=1}^{n} x_{1ijk}$, implying that partners are pooling similar resources and their investments are compensatory. The contest success function (1) implies that investing more *proportionally* increases the probability of success. This uncertainty captures the essence of technological uncertainties involved in new product development activities. Let the joint investment of the network winning the patent for the product based on technology path i be X_{1i}. T networks that win the product development competition advance to compete in the market.

In the *second stage* of the game, firms compete with one another either as *individuals* (Figure 2) or *jointly* as network (Figure 1). Assume that firm k, having won the patent rights for technology i, invests x_{2ik} units of its remaining capital toward developing the market ($0 \leq x_{2ik} \leq y_{ijk} - x_{1ijk}$).

Joint Development of the Market. If network partners jointly develop the market, then the joint investment in the product based on technology i is $X_{2i} = \sum_{k=1}^{n} x_{2ik}$. It is possible that investments in product development (stage 1) might not have the same impact as investments in market development (stage 2) in determining success in the marketplace. We allow for such a possibility by letting the probability that the patent holder of technology i wins the competition to be equal to

$$p_i = \frac{U_i}{\sum_{l=1}^{T} U_l}, \tag{2}$$

where $U_i = X_{2i} + \beta X_{1i}$ and $\beta \geq 0$. The parameter β is introduced to capture the *relative importance* of product and market development investments. If $\beta > 1$ (<1), then investments in product development have more (less) impact on winning the second phase of the competition. Partners in the network that wins the second stage of competition equally share the market of value V.

Given these assumptions, the expected payoff for firm k in network j pursuing technology path i is

$$E(x_{1ijk}, x_{2ijk}) = -x_{1ijk} + p_{1ij}\left[\left(\frac{V}{n}\right)p_i - x_{2ik}\right]. \tag{3}$$

In light of Equation (3), p_i can potentially be interpreted as the *market share* of technology i if the agents are risk neutral. This interpretation is consistent with choice models in marketing (e.g., Raju et al. 1994). For the sake of consistency, we shall continue referring to p_i as the probability of technology i winning the competition.[1]

Individual Development of Market. If network partners individually develop the market, then the competition in the market development phase spans across technologies and partnering firms as shown in Figure 2. Thus, the probability that firm k holding the patent rights for technology i wins the competition is given by (compare with Equation (2))

$$p_{ik} = \frac{U_{ik}}{\sum_{l=1}^{T}\sum_{s=1}^{n} U_{ls}}, \tag{4}$$

where $U_{ik} = x_{2ik} + \beta X_{1i}$, X_{1i} is the effective utility of product developed by the network that won the patent for technology i, and the parameter β captures the *relative importance* of product and market development investments. Now the expected payoff to firm k in network j developing technology i is given by (compare to Equation (3))

$$E(x_{1ijk}, x_{2ijk}) = -x_{1ijk} + p_{1ij}\left[V \cdot p_{ik} - x_{2ik}\right]. \tag{5}$$

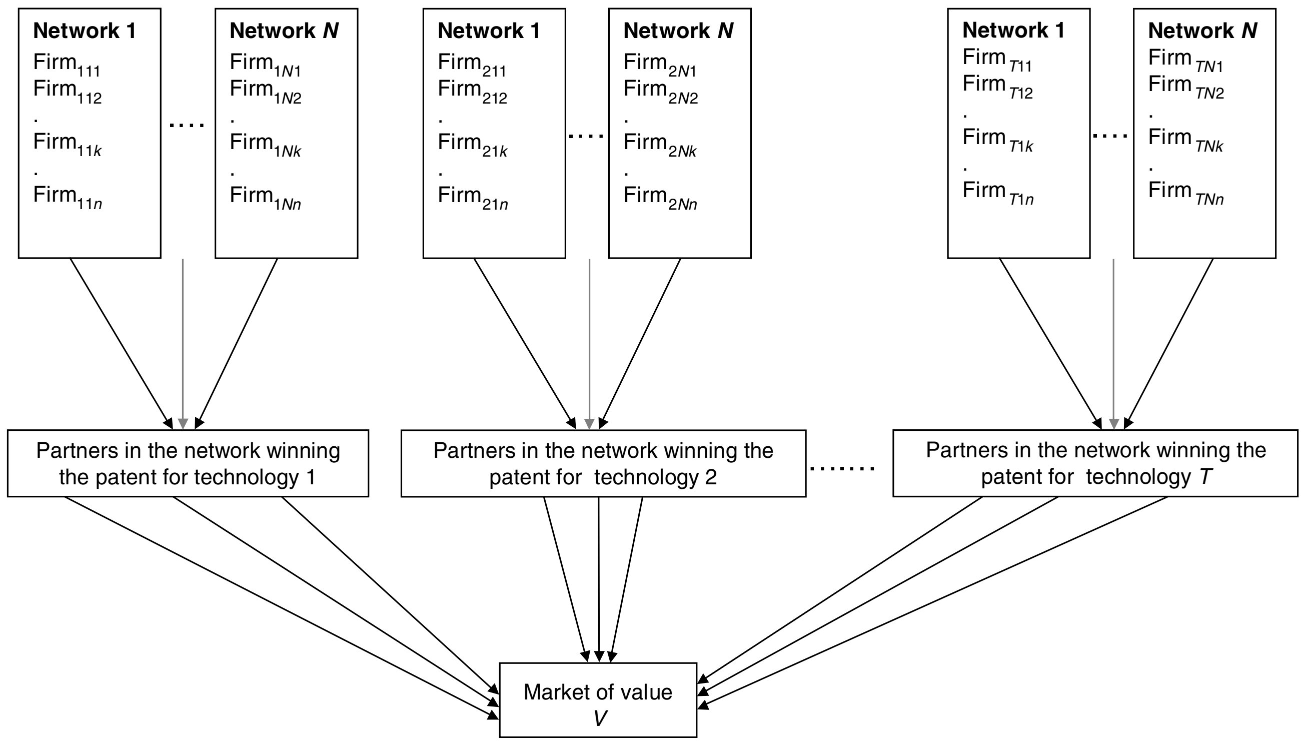
Analysis

Our strategy in this section is to first derive the theoretical implications of the basic model for joint development of market and then compare it with individual development of the market. In the appendix, we first solve for the second stage of the game and then solve for the first stage of the game to construct the symmetric subgame perfect equilibrium solution. Using this solution, we examine the effects of number of networks pursuing the same technology path (N), number of technological paths (T), and the extent to which the market is sensitive to investments in product development (β) on three different dependent variables: total joint investment across both stages ($X_{ij} = X_{1ij} + X_{2ij}$), joint investment in product development (X_{1ij}), and joint investment in market development (X_{2ij}). The qualitative implications of the model are summarized in the following four propositions.

Effect of Number of Networks. On examining the effect of number of networks on equilibrium investments in the internetwork competition, we find that joint investment in product development declines

[1] Amaldoss et al. (2000) proposed a model to study strategic alliances. Our model formulation differs from their model in several ways. First, their model is a single-stage game, whereas we consider a two-stage game. This shifts the focus of the investigation to the allocation of resources between the two stages of the competition. Second, their model examines competition between two dyads ($n_i = 2$), whereas we consider competition between networks with more than two partners ($n_i \geq 2$). Third, in their model the winning alliance is decided deterministically, whereas in our model the winning network is decided probabilistically. Fourth, the strategy space is discrete and limited to three levels in their model, whereas here we consider continuous strategy space. Fifth, they confine their analyses to competition between two alliances ($N = 2$), whereas we study competition among a large number of networks ($N \geq 2$). Finally, their game has a mixed-strategy equilibrium solution, while our model has a pure strategy solution.

Figure 2 **Joint Product Development and Individual Market Development**



while joint investment in market development is nondecreasing as the number of competing networks increases. The total investment in both product and market development increases only if the relative importance of product development is higher. Thus, we have Proposition 1.

Proposition 1. *$\partial X_{1ij}/\partial N < 0$ and $\partial X_{2ij}/\partial N \geq 0$. Furthermore, $\partial X_{ij}/\partial N \leq 0$ if $0 \leq \beta \leq 1$; but if $\beta > 1$, then $\partial X_{ij}/\partial N > 0$.*

Proof. See Appendix A.

The intuition for this result is as follows. An increase in the number of competing networks within a technology platform decreases the probability of winning the patent, and thereby reduces the expected gain from winning. Consequently, the investment in product development decreases ($\partial X_{1ij}/\partial N < 0$). Recall that the utility of a product depends on investments in both developing the product and the market, namely, $U_i = X_{2i} + \beta X_{1i}$. This allows for N to have an indirect effect on the investments in market development. We find that $\partial X_{2ij}/\partial X_{1ij} \leq 0$ if $\beta \geq 0$, implying that a drop in product development investment could induce a rise in market development investment. On further analysis, we note that $\partial X_{2ij}/\partial N = \beta|\partial X_{1ij}/\partial N| \geq 0$. This suggests that the effect of N on the total investment in product and market development would be positive (negative) if $\beta > 1$ ($\beta < 1$). In the special case of $\beta = 1$, the increase in market development investment is offset by the decrease in product development investment such that the total investment remains unchanged. In the polar case of $\beta = 0$, the two phases of inter-network competition are independent. Therefore, the number of networks competing to win stage 1 has no effect on investments in market development phase.

Proposition 1 has an important practical implication. Greater competition in developing the technology for a new product might dampen investments in developing the product and encourage higher investment in market development. The proposition also raises a related question: How would the results change if the game had only one stage. Consistent with the two-stage model, even in the single-stage game the joint investment of a network would decrease as the number of competing networks increases (see Amaldoss and Rapoport 2005). In contrast to our two-stage model, the single-stage model does allow us to examine the differential impact of number of competing networks on investments in product and market development.

Effect of Number of Technological Paths. Our second result is that an increase in the number technological paths depresses the total investment as well as the investment in product development, but the effect on market development varies with the number of technological paths.

Proposition 2. $\partial X_{ij}/\partial T < 0$. *Similarly,* $\partial X_{1ij}/\partial T < 0$, *but* $\partial X_{2ij}/\partial T > 0$, *if* $T < T^* = (2N(nN - \beta))/(n(\beta - \beta N + N^2) - \beta N)$ *and* $0 \leq \beta < (nN^2)/(2N - 1)$.

Proof. See Appendix A.

The value of the critical number of technology paths, T^*, decreases in both N and n. The intuition for this result is that when the number of technological paths increases it reduces the expected gain from winning the product development competition, and consequently dampens investments in product development. There are two opposing effects on investments in market. First, as T increases, it reduces the probability of winning the market-based competition and thus has a direct negative impact on investments in market development. Second, T has an indirect effect through its impact on the investments in product development. This indirect effect is positive as $\partial X_{1ij}/\partial T < 0$ and $\partial X_{2ij}/\partial X_{1ij} \leq 0$. We note that the net effect of T on the market development is positive only when $T < T^*$.

An implication of Proposition 2 is that as competition on the technology development front increases partnering firms could strategically shift their resources toward market development.

Effect of Market Sensitivity to Product Development Investments. Our analysis shows that as market sensitivity increases, investments in product development grow while investments in market development decline. The overall investment in both product and market development decreases.

Proposition 3. $\partial X_{1ij}/\partial \beta > 0$, *but* $\partial X_{2ij}/\partial \beta < 0$, *and* $\partial X_{ij}/\partial \beta < 0$.

Proof. See Appendix A.

This result is qualitatively different from Propositions 1 and 2, and its intuition is simple. When the market becomes more sensitive to investments in product development, equilibrium investments in product development rise. Consequently, network partners invest less in market development. This result implies that as the market becomes appreciative of the investments in a product, we are likely to see networks becoming more technology oriented and committing fewer resources for market development.

Effect of Individual Development of the Market. Allowing firms to compete individually (rather than collectively) in the marketplace dampens investments in product development and increases investments in market development. Hence, we have Proposition 4.

Proposition 4. *Individual development of market increases market development investments and the total investment in product and market development, but product development investments decrease.*

Proof. See Appendix B.

The qualitative effect of number of networks (N) and the effect of market sensitivity to investments in product development (β) are as in the case of joint development of markets. Our analysis suggests that as T increases it reduces competitive investments in both stages of the game.[2]

Model Extensions

As noted earlier, the scope of our investigation is limited. The noncooperative, two-stage, n-person game proposed in the basic model captures only some of the essential features of product and market development competitions such as technological and market uncertainties, sequential development process, and strategic uncertainty. Modeling complex processes like collaborative product and market development necessarily involves making simplifying assumptions. Our basic model assumes that there is no technology spillover, market size is fixed, there is only a single winner, technologies are symmetric, and the utility function is additive. Relaxing these assumptions through a series of model extensions, which we outline below, has contributed to a better understanding of the implications of these assumptions, especially the robustness of the implications of the basic model to these assumptions.

(1) The technology developed by a firm could leak because of factors such as information sharing, mobility of manpower, and difficulty in completely patenting the innovation (Griliches 1979, Jaffe 1986, Mansfield 1986). This *technology spillover* allows a network to innovate with less effort. Even in contexts where there is technology spillover, the earlier results on the effect of number of competing network and number of technological paths are applicable. When faced with the prospect of technology spillover, a firm in this scenario recognizes the fact that some of its investment is going to spillover to the competing networks and render them stronger competitors (see also Amir et al. 2003, Cohen and Levinthal 1989). This likely externality induces firms to invest less in technology development. *Ex-post*, the networks invest more in market development. The fact that spillover dampens investments is well recognized (Jaffe 1986). However, its differential impact on product and market development is not known.

(2) In the basic model the market size is fixed, but market size could be sensitive to investments in product and market development. On *endogenizing market size* and examining its impact on equilibrium behavior, we have found that the qualitative

[2] The additional analyses can be seen in the technical appendix, which can be obtained from the authors or from the *Marketing Science* website as http://mktsci.pubs.informs.org.

results in Propositions 1 through 3 remain valid. We considered an additive utility function in the basic model. In contexts where alliance partners pool complementary (rather than compensatory) resources, as in cross-function networks, a *multiplicative utility function* might be more appropriate. On allowing for a multiplicative utility function, we find that the results are directionally consistent with Proposition 1. Furthermore, investments in product as well as market decline as the number of technological paths increase.

(3) In our model we used *Tullock's contest success function* to capture the uncertainties associated with product and market development (see Equations (1), (2), and (4)). This function is similar to the choice rule of Luce (1959), which is extensively used to model consumer choice. Although we assumed such a contest success function in our model, its axiomatic foundations are discussed in Skaperdas (1996) and Clark and Riis (1998a). More recently, Baye and Hoppe (2003) have established the strategic equivalence of contests based on Tullock's success function, innovation tournaments (e.g., Fullerton and McAfee 1999), and patent races (e.g., Loury 1979). We also note that the qualitative results of the model are applicable to a class of contest success functions that include the logit formulation.[3]

(4) We also have assumed that the networks and technologies are symmetric. This assumption is quite restrictive, as in general networks and technologies are asymmetric. For example, the relative efficiency of competing technologies could vary. Such an asymmetry could potentially provoke the network developing the superior technology to invest more aggressively, while making the network developing the inferior technology try harder to win the competition. Our preliminary analysis suggests that the advantaged networks are only selectively aggressive: invest more in the product but less in the market. The disadvantaged network does not try harder. On the contrary, such networks invest less as the level of asymmetry increases. Thus, perhaps not surprisingly, technology asymmetry might dampen competitive investments.

(5) Many markets include multiple winners. Furthermore, there is often an implicit ordering in the gains that accrue to these winners that it is based on the order of entry (e.g., Robinson and Fornell 1985, Clark and Riis 1998b). On allowing for multiple winners and ordered market rewards, we find that the qualitative implications of Propositions 1 through 3 are valid. In this scenario, as networks have more than a single opportunity to win some part of the market, they are motivated to invest more in product development and win the first stage of the competition. This motivation grows stronger as the market available for the later entrants increases. In this setting it is useful to note that the value of the market that any single network can possibly win is now reduced because of leaving some residual market for the later entrant. This reduction dampens investments in market development. Also, the total investment in both product and market development drops. Hence, in markets with more pioneering advantage (less residual market for later entrant) alliances might invest less to develop the product and more to develop the market. The prospect of pioneering advantage possibly motivated Apple Newton to rush to the market (Bayus et al. 1997).

3. Experimental Investigation

A computer-controlled experiment was conducted to determine whether financially motivated agents behave in accordance with theory in a controlled laboratory setting that conforms to the structure of the model (e.g., Zwick et al. 2003). A few caveats are in order. We are not testing the model assumptions, only their implications. We recruit students rather than alliance managers as subjects and reward them for their performance very modestly. Furthermore, each firm is represented by an individual subject, rather than a committee of people, as is common in organizations. Thus, the experimental investigation forms only an initial step in assessing the descriptive power of our model. Caution should be exercised in generalizing its results to field settings

It is not obvious that the model predictions would survive a laboratory test. Clearly, subjects do not compute the equilibrium and accordingly make investments in each stage of the game. Furthermore, individuals might form their investment decisions on the basis of simple heuristics that have limited normative basis. In our experimental investigation we use repeated games and study only same-function networks. The experimental investigation addresses the following two questions:

1. Would network partners invest more in market development and less in product development as the number of competing networks (N) and technologies (T) increases?

2. Do networks shift their investments in product and market development according to how sensitive the market is to investments in product development (β)?

[3] Specifically, consider a first-stage contest success function $p_{1ij}[X_{1ij}, \sum_{m=2}^{N} X_{1im}]$ such that $\partial p_{1ij}/\partial x_{1ik} > 0$, $\partial^2 p_{1ij}/\partial x_{1ik}^2 < 0$, $\partial p_{1ij}/\partial N < 0$, and $\partial^2 p_{1ij}/\partial x_{1ik}\partial N < 0$. These conditions imply that the probability of winning increases at a decreasing rate as a firm increases its investment in product development. Also, the probability of winning reduces as more networks compete. Let the second-stage contest success function be $p_i[U_i, \sum_{l=2}^{T} U_l]$ such that $\partial p_i/\partial x_{2ik} > 0$, $\partial^2 p_i/\partial x_{2ik}^2 < 0$, $\partial^2 p_i/\partial x_{2ik}\partial x_{1ik} < 0$, $\partial^2 p_i/\partial x_{2ik}\partial T < 0$, $\partial^2 p_i/\partial x_{1ijk}\partial T < 0$, and $\partial p_i/\partial T < 0$.

Subjects
The subjects who participated in Study 1 were all business school students. We recruited business school students because it is convenient to do so. It is also easier to motivate students because their opportunity cost is lower compared to alliance managers. All the subjects volunteered to take part in a decision making experiment for payoff contingent on performance. They were paid a show-up bonus of $5 in addition to monetary reward contingent on their performance. All transactions were in an experimental currency, called "francs," that was converted into U.S. dollars at the end of the experiment. The mean individual payoff was approximately $15.

Experimental Design
Using a between-subject design, we conducted one session of each of four different treatments (conditions), namely, $[J, n = 2, N = 2, T = 2, \beta = 1]$, $[J, n = 2, N = 4, T = 2, \beta = 1]$, $[J, n = 2, N = 2, T = 4, \beta = 1]$, and $[J, n = 2, N = 2, T = 2, \beta = 0]$.[4] For instance, subjects in condition $[J, n = 2, N = 2, T = 2, \beta = 1]$ were placed in networks with two partners ($n = 2$), two such networks competed to win the patent rights for a technology ($N = 2$), two technologies competed to gain a share of the market ($T = 2$), and the market-based competition was sensitive to investments in product development ($\beta = 1$). While $n = 2$ in all four conditions, the conditions vary in the values of N, T, and β. Using a between-subject design, 16 subjects participated in each condition for a total of 64 subjects in Study 1. Each subject participated in 80 rounds of the two-stage product and market development game.

Procedure
Upon arriving at the laboratory, the subjects were randomly seated in 16 booths. They were then asked to read the instructions, which included a detailed example. Then the subjects participated in five practice trials to familiarize them with the task and ensure their understanding. If they had any questions during these practice trials, these questions were answered. Communication between the subjects during the course of the experiment was prohibited.

At the beginning of the experiment, each subject was informed of the number of partners in a network ($n = 2$), the number of networks competing within a given technology platform ($N \in \{2, 4\}$), the number of alternative technology platforms ($T \in \{2, 4\}$), whether the competition in the marketplace was sensitive to investments in product development ($\beta \in \{0, 1\}$), and the trial number. At the beginning of each trial, each subject was endowed with 17 francs in all four experimental conditions ($y_{ijk} = 17$). The value of the total market was $V = 160$. Consequently, the individual reward for winning the competition was 80 francs.

In the first stage of each trial, the 16 subjects in each condition were randomly divided into pairs to form 8 networks of 2 players each. Each network was set to compete with $N - 1$ networks. The random assignment schedule ensured that each subject was networked with a different subject and competed against a different set of networks. The subjects had no way of knowing the identity of their partners or their competitors. All this was done to reduce, if not entirely eliminate, reputation effects that are not accounted for by our static model.

Based on the number of partners, number of competing networks, number of technologies, and reward for winning the competition, each subject had to decide what portion of her capital to invest in the product to be jointly developed by her network. Subjects could invest any amount (including zero), provided the investment did not exceed the endowed capital ($0 \leq x_{ijk} \leq y_{ijk}$). After all the subjects typed in their investments privately and anonymously, the computer assessed the joint investments made by the networks. The winning network was determined probabilistically by the computer in proportion to the relative investments. At the end of the first stage, subjects were informed of the joint investments made by the winning and losing networks and the probability of their network winning the competition. The winners advanced to the second stage of the game.

In the second stage of the game, networks holding patent rights for the different technologies competed for developing the market. Each partner in these networks decided how much to invest in developing the market for the new product ($0 \leq x_{2ijk} \leq y_{ijk} - x_{1ijk}$). If $\beta = 1$, then the success of a network depended on the total investments made in developing the technology and the market, but if $\beta = 0$, then the success in this stage of the competition depended only on investments in the market. The winner of stage 2 of the competition was determined probabilistically. At the end of stage 2, subjects were informed of the probability of their network winning the competition and the total investments made by the winning and losing networks. Members of the network that won the second stage of the competition received the reward. Irrespective of the outcome of the competition, the investments in product and market development were forfeited.

At the end of each trial, subjects were informed of their own payoff for the trial as well as their

[4] To conserve space, we use the notation $[J, n = 2, N = 2, T = 2, \beta = 1]$ to denote the condition where networks jointly develop and market the product, with other parameters being $n = 2$, $N = 2$, $T = 2$, and $\beta = 1$. Likewise, $[J, n = x, N = y, T = z, \beta = 1]$ denotes the corresponding condition with parameters $n = x$, $N = y$, $T = z$, and $\beta = 1$.

cumulative payoff. Information about the payoffs of other players was not provided. Subjects were provided with paper and pencil for recording the outcomes of previous decisions, if they wished to do so. The stage game was iterated for 80 rounds to allow for learning. At the end of the experiment, subjects were paid according to their cumulative earnings, debriefed, and dismissed.

Linkage Between Experiment and Theory. Subjects played a sequential two-stage game with a probabilistic contest success function, as formulated in the theoretical model. Furthermore, the market size was fixed, and partners in the winning network shared the market prize. The competing networks and technologies were symmetric. Therefore, the experiment simulates the structure of the basic model. Clearly, it does not control for the behavioral assumptions about economic agents such as risk neutrality, nor does it account for other individual differences.

Results

Our analysis focuses on assessing the descriptive power of the equilibrium predictions derived in the previous sections. We discuss separately tests of the *qualitative* implications of the equilibrium solution that are summarized by Propositions 1 through 3 and tests of the *quantitative* implications that are considerably easier to refute. Although we mostly focus on aggregate results by comparing to each other different pairs of the experimental conditions, we also comment briefly on individual differences. The aggregate level analysis combines data from all 80 trials. Table 1 summarizes the point predictions and the empirical results. We report mean investments of networks. The individual partner means are simply obtained by dividing the reported network means by two. With two partners in each network, the maximum total joint investment is $17 \times 2 = 34$.

Effect of Number of Competing Networks (N)**.** As the value of N increases and all other parameters remain constant, the total joint investment in product and market development should remain the same (column 8 of Table 1), the investment in product development should decrease, and the investment in market development should increase. To test these three directional hypotheses (Proposition 1), we compared to each other the mean observed investments in conditions $[J, n = 2, N = 2, T = 2, \beta = 1]$ and $[J, n = 2, N = 4, T = 2, \beta = 1]$ that differ from each other only in the value of N. Consistent with the equilibrium predictions, when the number of competing networks was increased from 2 to 4, the difference between these two conditions in mean total joint investment in product and market development was not significant ($N = 2$: mean $X_{ij} = 21.91$, $N = 4$: mean $X_{ij} = 21.59$, $F_{(1,158)} = 0.6$, $p > 0.43$). Also as predicted, subjects in networks with two partners invested significantly more in product development ($N = 2$: mean $X_{1ij} = 11.56$, $N = 4$: mean $X_{1ij} = 9.09$, $F_{(1,158)} = 123$, $p < 0.001$), and significantly less in market development ($N = 2$: mean $X_{2ij} = 10.36$, $N = 4$: mean $X_{2ij} = 12.50$, $F_{(1,158)} = 183$, $p < 0.001$) than subjects in networks with four partners.

Turning next to the *quantitative* implications of the equilibrium solution, comparison of the mean observed investments to the equilibrium point predictions (in boldface type) provides support to the equilibrium solution. In equilibrium, networks in condition $[J, n = 2, N = 2, T = 2, \beta = 1]$ should invest 12 and 8 units in product and market development, respectively (row 1 of Table 2). We cannot reject these two predictions (mean $X_{1ij} = 11.56$, $t = 0.46$, $p > 0.3$; and mean $X_{2ij} = 10.36$, $t = 1.17$, $p > 0.12$). Subjects in condition $[J, n = 2, N = 4, T = 2, \beta = 1]$ should invest 7.2 and 12.8 units in product and market development, respectively (row 2 of Table 1). Again, we cannot reject these two null hypotheses (mean

Table 1 Experimental Results: Mean Investment Made by Same-Function Networks in Product and Market Development

		Product development		Market development		Total investment	
Treatment	Condition parameters	Observed investment	Equilib.	Observed investment	Equilib.	Observed investment	Equilib.
Study 1: Joint development of product and market							
1	$[J, n=2, N=2, T=2, \beta=1]$	11.56	**12.00**	10.36	**8.00**	21.91	**20.00**
2	$[J, n=2, N=4, T=2, \beta=1]$	9.09	**7.20**	12.50	**12.80**	21.59	**20.00**
3	$[J, n=2, N=2, T=4, \beta=1]$	7.94	**5.00**	11.91	**10.00**	19.86	**15.00**
4	$[J, n=2, N=2, T=2, \beta=0]$	12.35	**7.50**	15.29	**20.00**	27.64	**27.50**
Study 2: Joint development of product and individual development of market							
5	$[I, n=2, N=2, T=2, \beta=1]$	8.39	**5.00**	18.04	**20.00**	26.43	**25.00**
6	$[I, n=2, N=2, T=2, \beta=0]$	7.30	**1.25**	22.39	**30.00**	29.68	**31.25**

Note. Each network is comprised of two partners. A total of 16 subjects participated in each treatment, and the mean is computed across eighty trials. Also note that $V = 160$ in treatments 1–4 and $V = 80$ in treatments 5 and 6.

$X_{1ij} = 9.09$, $t = 1.08$, $p > 0.13$; and mean $X_{2ij} = 12.50$, $t = 0.11$, $p > 0.45$).

Effect of Number of Alternative Technological Paths (T)**.** Proposition 2 states that as the value of T increases, the total investment in both phases of the game should decrease, the investment in product development phase should also decrease, but the investment in market development phase should increase. These hypotheses were tested by comparing to each other the mean investments in conditions $[J, n = 2, N = 2, T = 2, \beta = 1]$ and $[J, n = 2, N = 2, T = 4, \beta = 1]$ that only differ from each other in the value of T. All three null hypotheses could not be rejected. As T was increased from 2 to 4, total joint investment decreased ($T = 2$: mean $X_{ij} = 21.91$, $T = 4$: mean $X_{ij} = 19.86$, $F_{(1,158)} = 34.70$, $p < 0.001$), investment in product development also declined ($T = 2$: mean $X_{1ij} = 11.56$, $T = 4$: mean $X_{1ij} = 7.94$, $F_{(1,158)} = 337$, $p < 0.001$), but investment in market development increased ($N = 2$: mean $X_{2ij} = 10.36$, $N = 4$: mean $X_{2ij} = 11.91$, $F_{(1,158)} = 20.82$, $p < 0.001$).

Shifting to the point predictions, in equilibrium players in condition $[J, n = 2, N = 2, T = 4, \beta = 1]$ should invest 5 and 10 units in the product and market development phases, respectively (row 3). The first of these point predictions was rejected, because subjects invested significantly more in the product development phase than predicted (mean $X_{1ij} = 7.94$, $t = 0.46$, $p < 0.03$). The second point prediction concerning investment in market development could not be rejected (mean $X_{2ij} = 11.91$, $t = 0.83$, $p = 0.20$).

Effect of Market Sensitivity to Investments in Product Development (β)**.** Proposition 3 implies that as the sensitivity parameter β increases, investments in product development should grow but investments in market development should decline as should the total investment in product and market development. Two of these three hypotheses could not be rejected. Comparison of conditions $[J, n = 2, N = 2, T = 2, \beta = 0]$ and $[J, n = 2, N = 2, T = 2, \beta = 1]$ (Table 1, rows 4 and 1), which differ from each other only in the sensitivity parameter, shows that networks invested significantly less in product development when the value of β was changed from 0 to 1 ($\beta = 0$: mean $X_{1ij} = 12.35$, $\beta = 1$: mean $X_{1ij} = 11.56$, $F_{(1,158)} = 25.09$, $p < 0.001$). However, in accordance with the equilibrium prediction, the investments in market development declined as β increased in value ($\beta = 0$: mean $X_{2ij} = 15.29$, $\beta = 1$: mean $X_{2ij} = 10.36$, $F_{(1,158)} = 217.76$, $p < 0.001$), and the total investment in product and market development also declined ($\beta = 0$: mean $X_{ij} = 27.64$, $\beta = 1$: mean $X_{ij} = 21.91$, $F_{(1,158)} = 252.32$, $p < 0.001$).

In equilibrium, networks in condition $[J, n = 2, N = 2, T = 2, \beta = 0]$ should invest 7.5 and 20 units in product and market development, respectively. Both of these hypotheses were rejected by the data (mean $X_{1ij} = 12.35$, $t = 4.6$, $p < 0.01$; mean $X_{2ij} = 15.29$, $t = 2.12$, $p < 0.02$). In actuality, networks invested significantly more in product development and significantly less in market development than predicted. However, we cannot reject the null hypothesis that the observed and predicted total investments in product and market development are the same (mean $X_{ij} = 27.64$, $t = 0.06$, $p > 0.47$).

Trends in Investment. In all the analyses conducted thus far the individual investments were collapsed across the 80 rounds of play and could, therefore, mask potential learning effects. Statistical analysis of the mean investments in blocks of ten trials each (one-way ANOVA with repeated measures) yielded significant block effects in the product development phase for only one of the four conditions. Although statistically significant, the block effect was marginal ($p < 0.1$). There were no significant block effects in the market development phase for any of the four conditions. A potential implication of the trend analysis is that the structure of our two-stage game, with noisy feedback because of the probabilistic contest success function, poses greater challenge for learning. The trends in product and market development investments for each of the treatments are presented in the Technical Appendix at http://www.mktsci.pubs.informs.org.

Individual Investments. Although the aggregate behavior of networks was, in general, accounted quite well by the theoretical predictions, there were substantial variations in the mean investments of individual subjects. The upper panel of Table 2 presents the distribution of the mean investments of individual subjects in networks that jointly developed and marketed products. In equilibrium, each subject in condition $[J, n = 2, N = 2, T = 2, \beta = 1]$ should invest $12/2 = 6$ units in product development. The mean investments of our subjects actually ranged from 1 to 9, with a standard deviation of 2.39. We see eight subjects falling in the interval $(4, 7]$. Subjects in condition $[J, n = 2, N = 4, T = 2, \beta = 1]$ should invest $7.2/2 = 3.6$ units. In fact, the observed mean investments ranged from 2 to 9, with a standard deviation of 1.77, and 11 of the 16 subjects falling in the interval $(2, 5]$. While subjects in condition $[J, n = 2, N = 2, T = 4, \beta = 1]$ were expected to invest 2.5 units, the observed mean investments of only seven subjects fell in the range $(2, 4]$, and the standard deviation in the investments was 1.45. Finally, the predicted investments of subjects in condition $[J, n = 2, N = 2, T = 2, \beta = 0]$ is 3.75 units, Table 2 shows only four subjects with mean investments in the region $(2, 5]$, and the standard deviation was 2.11. We observe similar between-subject variations in market development

Table 2 Distribution of the Mean Investment of Individual Subjects

		Investment class																
Stage of game	Condition	$0 \le x_{ijk} \le 1$	$1 < x_{ijk} \le 2$	$2 < x_{ijk} \le 3$	$3 < x_{ijk} \le 4$	$4 < x_{ijk} \le 5$	$5 < x_{ijk} \le 6$	$6 < x_{ijk} \le 7$	$7 < x_{ijk} \le 8$	$8 < x_{ijk} \le 9$	$9 < x_{ijk} \le 10$	$10 < x_{ijk} \le 11$	$11 < x_{ijk} \le 12$	$12 < x_{ijk} \le 13$	$13 < x_{ijk} \le 14$	$14 < x_{ijk} \le 15$	$15 < x_{ijk} \le 16$	$16 < x_{ijk} \le 17$
Study 1: Joint development of product and market																		
Product development	$[J, n=2, N=2, T=2, \beta=1]$	1	1	1	0	2	3	**3**	3	1	1	0	0	0	0	0	0	0
	$[J, n=2, N=4, T=2, \beta=1]$	0	0	2	**5**	4	2	2	0	1	0	0	0	0	0	0	0	0
	$[J, n=2, N=2, T=4, \beta=1]$	1	0	2	5	**2**	6	0	0	0	0	0	0	0	0	0	0	0
	$[J, n=2, N=2, T=2, \beta=0]$	0	0	2	**1**	1	4	2	4	1	0	0	1	0	0	0	0	0
Market development	$[J, n=2, N=2, T=2, \beta=1]$	0	0	3	**2**	3	3	1	3	0	0	1	0	0	0	0	0	0
	$[J, n=2, N=4, T=2, \beta=1]$	0	0	2	2	2	4	**2**	1	0	0	0	1	1	1	0	0	0
	$[J, n=2, N=2, T=4, \beta=1]$	0	0	0	4	**1**	3	3	3	2	0	0	0	0	0	0	0	0
	$[J, n=2, N=2, T=2, \beta=0]$	0	0	0	1	1	1	2	3	5	**2**	0	0	0	1	0	0	0
Study 2: Joint development of product and individual development of market																		
Product development	$[I, n=2, N=2, T=2, \beta=1]$	1	2	**4**	3	2	0	1	2	0	0	0	0	0	0	0	0	0
	$[I, n=2, N=2, T=2, \beta=0]$	**4**	3	1	0	2	3	0	2	1	0	0	0	0	0	0	0	0
Market development	$[I, n=2, N=2, T=2, \beta=1]$	0	0	1	0	0	1	2	1	1	**4**	0	3	1	1	1	0	0
	$[I, n=2, N=2, T=2, \beta=0]$	0	0	0	0	0	0	1	1	0	5	0	1	2	1	**2**	2	1

Note. Cells in which the equilibrium solution falls appear in boldface.

investments in violation of the model that does not account for individual differences. Such individual level differences have also been reported in experimental games such as mixed strategy games (Rapoport and Amaldoss 2000, 2004; Amaldoss and Jain 2002) and rational expectation games (Amaldoss and Jain 2005).

Study 2

The results of Study 1 on joint product and market development are qualitatively consistent with the predictions of the basic model. The following question arises: Would individual (rather than joint) development of the market dampen investments in product development and increase investments in market development? To answer this question we conducted an additional study with a new group of 32 subjects. Study 2 included two new conditions in which partners competed individually in the market development stage of the game, namely, conditions $[I, n=2, N=2, T=2, \beta=1]$ and $[I, n=2, N=2, T=2, \beta=0]$. The experimental procedure closely followed Study 1, except that now partners competed independently in the market and the reward for winning was 80 ($V=80$). In equilibrium (Proposition 4), individual development of the market lowers investment in product development but raises investment in market development. Our analysis rejects the null hypothesis that individual and joint development of the market have the same effect on investment in product development ($F_{(1,316)}=1319, p<0.001$). It also rejects the null hypotheses regarding investment in market development ($F_{(1,316)}=841, p<0.001$), and the total investment in market and product development ($F_{(1,316)}=169, p<0.001$). On average, networks in condition $[J, n=2, N=2, T=2, \beta=1]$ invested 11.56 and 10.36 in joint product development and market development, respectively, compared with 8.39 and 18.04 in condition $[I, n=2, N=2, T=2, \beta=1]$. Again as predicted, similar results were obtained when the sensitivity index was set to $\beta=0$. Networks in condition $[J, n=2, N=2, T=2, \beta=0]$ invested 12.35 and 15.29 in joint product development and market development, respectively. In contrast, networks in condition $[I, n=2, N=2, T=2, \beta=0]$ invested fewer resources in joint product development (7.30), but more in individual market development (22.39). In Study 2, there were no significant trends in the investments in product and market development. As in Study 1, we observe substantial differences at the individual level. The distributions of mean investments of the individual subjects are reported in Table 2. We conclude that the observed investment behavior in both studies is qualitatively consistent with the model predictions.

4. Limitations and Directions for Future Research

Collaborative product and market development takes multiple forms. It is quite possible that no single comprehensive model can capture all these forms without losing tractability and predictability. In this paper we have taken only a small step toward understanding the process. Section 2 outlines a few salient features of the process and the assumptions that formed the basis of our theoretical analysis. Future research could extend the theoretical analysis by relaxing some of its simplifying assumptions. We have assumed sequential development of product and market. In some cases it might be beneficial to simultaneously develop the product and market. Future research can examine implications of such a *parallel development process*. In our model formulation, each network invested in only one technology. In reality, alliances could choose to diversify their investments across several technologies and potentially win multiple patents. A challenge for future research is to examine the implications of allowing alliance partners to invest in *multiple technologies*. In our model, partnering firms are not resource constrained. However, firms could face budget constraints because of inefficiencies in the financial markets. It would be instructive to examine how *budget constraints* influence relative investments in product and market development.

In our model, partnering firms were pre-assigned to networks. It would be useful to consider making the network *partnership decision endogenous* to the model. In developing the model, we considered a product development phase and market development phase. The theoretical implications of extending the model to *multiple periods* ($t > 2$) are yet to be explored. In formulating the model, we used Tullock's contest success function to determine the winner in each stage of the competition. Future research may consider using *alternative winning rules* (e.g., discriminatory rather proportional contest success functions). All the firms, networks, and technologies in the basic model are assumed to be symmetric. Examining the theoretical implication of allowing for different types of *asymmetry* among players, networks, or technologies is yet another challenge for future research. Furthermore, in our model we assumed that consumers' tastes for the different technologies are uncorrelated. It is easy to visualize contexts where the technologies have a hierarchical structure because of underlying correlation in consumer taste for these technologies. Future research can consider capturing such hierarchy by using a *nested structure*.

Additional avenues for further empirical research merit consideration. Future research might attempt to validate the model using longitudinal field data, and test the several model extensions briefly discussed in the paper. Furthermore, our experimental investigation raises some new questions. In general, the tendency to over-invest is weaker in our experiments compared to those reported in the rent seeking literature, where individuals (not groups) compete in a single-stage contest (e.g., Millner and Pratt 1989, 1991; Davis and Reilly 1998; Shogren and Baik 1991; Potters et al. 1999; Onculer and Croson 2003). Our subjects might have invested closer to the equilibrium prediction because we provided them greater opportunity to learn from experience and avoided some of the pitfalls in the earlier experimental designs. Finally, the desire to free ride might have dampened the enthusiasm to invest more.[5] Even in instances where observed behavior departed from equilibrium prediction, we see a common pattern (Table 1): Subjects expended more resources in the product development stage and not enough in the market development stage. A possible explanation for this finding is that our subjects might have assigned a positive utility to winning stage 1 (and, therefore, moving to stage 2) above and beyond the financial implications of winning the prize. If this explanation is correct, then the discrepancy between the observed and predicted results would be expected to decrease as the size of stakes in the experiment increases. The evidence showing considerable individual differences, not accounted for by our model, presents a challenge for future research. It is possible that heterogeneity in risk attitude could potentially account for the individual differences. In our model, we assumed that the winner takes all, and accordingly—while implementing the model—we let the winner take the entire market. However, under the assumption of risk neutrality, letting the winner capture the entire market is mathematically equivalent to awarding each alliance a share of the market in stage 2 of the game in proportion to the relative investments. It remains an empirical question whether the behavior of subjects would stay the same under these two alternative framings of winning the market.

[5] Some of the common pitfalls in single-stage contests are using sequential rather than simultaneous decision making, using fixed pairing instead of random pairing, placing binding budget constraints.

5. Conclusions

Our research was designed to examine how partnering firms allocate resources to the two distinct phases of collaboration: product and market development. Toward this goal we have formulated a parsimonious noncooperative two-stage game of inter-network competition and examined its implications both theoretically and experimentally. When the number of either competing networks or technologies increases, investments are more likely to be directed toward market rather than product development. Thus competition might moderate the orientation of a firm toward market and technology. We also note that forcing alliance partners to compete individually might not attenuate the under-investment problem associated with new product alliances. Then we have extended the basic model by considering alternative assumptions about the institutional arrangements governing the competition among the networks. Experimental results from two studies were consistent with the model qualitative predictions, although we observe substantial individual differences. We conclude by noting that collaborative product and market development remains a promising avenue for research as highlighted in the discussion of limitations and directions for future research.

Acknowledgment

This research was supported by grants from the National Science Foundation (NSF Grants SES-089182 and SES-0114138). The authors thank the editor, three reviewers, and in particular the area editor for very constructive comments. The authors also thank seminar participants at Emory University, the University of Illinois, and Duke University.

Appendix A*

Section A. Joint Development of Product and Market Development

Section A.1. Lemmas A1 and A2

We first prove Lemmas A1 and A2. Then using the two lemmas we prove Propositions 1, 2, and 3.

Lemma A1.

$$X_{1ij} = \frac{V(N-1)(nT-T+1)}{nT^2(nN^2-2N\beta+\beta)}. \tag{A1}$$

Proof. The probability of technology i winning the competition in the second stage of the game is:

$$p_i = \frac{U_i}{\sum_{l=1}^{T} U_l}, \tag{A2}$$

where

$$U_i = X_{2i} + \beta X_{1i} \quad \text{and} \quad \beta \geq 0. \tag{A3}$$

X_{2i} is the joint investment made in the second stage of the game in technology i, while X_{1i} is the joint investment made by the network that won the patent for technology i in the first stage of the competition. (As before, we define $p_i = 1/T$, if $U_i = 0\ \forall\, i$. However, $U_i = 0\ \forall\, i$ is not an equilibrium as any player can invest $\varepsilon > 0$ and win the competition to receive $V/n > \varepsilon$.)

The expected payoff to partner k in the network developing the market for technology i is:

$$\Pi_{2ik} = p_i\left(\frac{V}{n}\right) - x_{2ik}. \tag{A4}$$

We replace X_{2i} with $x_{2ik} + \sum_{s=2}^{n} x_{2is}$, and differentiate Π_{2ik} with respect to x_{2ik}:

$$\frac{\partial \Pi_{2ik}}{\partial x_{2ik}} = -1 + \frac{V\sum_{i=2}^{T} U_i}{n\left(\sum_{l=2}^{T} U_l + \beta X_{1l} + x_{2ik} + \sum_{s=2}^{n} x_{2is}\right)^2} = 0. \tag{A5}$$

Π_{2ik} is concave in x_{2ik} as

$$\frac{\partial^2 \Pi_{2ik}}{\partial x_{2ik}^2} = -\frac{2V\sum_{l=2}^{T} U_l}{n\left(\sum_{l=2}^{T} U_l + \beta X_{1l} + x_{2ik} + \sum_{s=2}^{n} x_{2ik}\right)^3} < 0. \tag{A6}$$

Now we solve for U_i. Replace $\beta X_{1i} + x_{2ik} + \sum_{s=2}^{n} x_{2is}$ with U_i in Equation (A5). Further, as the networks are symmetric, $\sum_{l=2}^{T} U_i = (T-1)U_i$. On simplifying, we obtain:

$$U_i = \frac{V(T-1)}{nT^2}. \tag{A7}$$

On substituting (A7) in (A2) and simplifying, we obtain:

$$p_i = \frac{1}{T}. \tag{A8}$$

Substitute (A8) in (A4). Then the expected payoff on winning the second stage of the game becomes:

$$\Pi_{2ik} = \frac{1}{T}\left(\frac{V}{n}\right) - x_{2ik}. \tag{A9}$$

From (A3) and (A7) we know that:

$$\beta X_{1i} + X_{2i} = \frac{V(T-1)}{nT^2}. \tag{A10}$$

$$X_{2i} = \frac{V(T-1)}{nT^2} - \beta X_{1i}. \tag{A11}$$

$$x_{2ik} = \left(\frac{V(T-1)}{nT^2} - \beta X_{1i}\right)\Big/ n. \tag{A12}$$

The probability that network j wins the patent for technology i is:

$$p_{1ij} = \frac{U_{1ij}}{\sum_{j=1}^{N} U_{1ij}}. \tag{A13}$$

Therefore, the expected payoff for player k in network j on winning the patent for technology i is:

$$\Pi_{1ijk} = -x_{1ijk} + p_{1ij} \cdot \Pi_{2ik}. \tag{A14}$$

On substituting (A9) and (A13) in (A14) and simplifying we obtain:

$$\Pi_{1ijk} = -x_{1ijk} + \left[\left(x_{1ijk} + \sum_{s=2}^{n} x_{1jks}\right)\left(V - TV + nTV + n\beta T^2\left(x_{1ijk} + \sum_{s=2}^{n} x_{1ijs}\right)\right)\right] \Big/ \left[n^2T^2\left(\sum_{m=2}^{N} U_{1im} + x_{1ijk} + \sum_{s=2}^{n} x_{1ijs}\right)\right] \tag{A15}$$

*See Appendixes B through D, at http://mktsci.pubs.informs.org.

$$\frac{\partial \Pi_{1ijk}}{\partial x_{1ijk}} = \left[n(\beta-n)+\left(\sum_{m=2}^{N}U_{1im}\left((1+T(n-1))V - n\beta T^2\sum_{m=2}^{N}U_{1im}\right)\right)\Big/ \left(T^2\left(\sum_{m=2}^{N}U_{1im}+x_{1ijk}+\sum_{s=2}^{n}x_{1js}\right)^2\right)\right]\Big/ n^2=0. \quad \text{(A16)}$$

We know that $\sum_{m=2}^{N} U_{1im} = (N-1)X_{1ij}$ and $\sum_{s=2}^{n} x_{1ijs} = (n-1)x_{1ijk}$, as the networks and players are symmetric. On simplifying the second derivative and noting that $N \geq 2$ and $n \geq 2$, we find that there is an interior maximum:

$$\frac{\partial^2 \Pi_{1ijk}}{\partial x_{1ijk}^2} = -\frac{(N-1)(1+(n-1)T)V}{n^3N^2T^2x_{1ijk}^2} < 0. \quad \text{(A17)}$$

In (A16), if we replace $x_{1ijk} + \sum_{s=2}^{n} x_{1ijs}$ with X_{1i}, and then solve for X_{1i}, we obtain:

$$X_{1ij} = \frac{(N-1)(1-T+nT)V}{nT^2(nN^2-2\beta N+\beta)}. \quad \square$$

Lemma A2.

$$X_{2ij} = \frac{V(\beta N - nN^2 + \beta nT - \beta NT - \beta nNT + nN^2T)}{nT^2(nN^2-2\beta N+\beta)}. \quad \text{(A18)}$$

Proof. We know from (A10):

$$X_{2i} = \frac{V(T-1)}{nT^2} - \beta X_{1i}.$$

Using Lemma A1, we simplify the above expression and obtain:

$$X_{2i} = \frac{V(\beta N - nN^2 + \beta nT - \beta NT - \beta nNT + nN^2T)}{nT^2(nN^2-2\beta N+\beta)}. \quad \square$$

Section A.2. Effects of Number of Networks (Proposition 1)

The three claims made in Proposition 1 are proved below.

Claim A2a. $\partial X_{1ij}/\partial N < 0$.

Proof. From Lemma A1 we have:

$$X_{1ij} = \frac{(N-1)(1-T+nT)V}{nT^2(nN^2-2\beta N+\beta)}$$

$$\frac{\partial X_{1ij}}{\partial N} = -\frac{(1+T(n-1))(nN(N-2)+\beta)V}{nT^2(nN^2-2\beta N+\beta)^2}. \quad \text{(A19.1)}$$

As $N \geq 2$, the numerator is positive. The denominator is positive as well, and hence the expression is negative:

$$\frac{\partial X_{1ij}}{\partial N} < 0. \quad \square$$

Claim A2b. $\partial X_{2ij}/\partial N \geq 0$, if $\beta \geq 0$.

Proof. We know from Lemma A2:

$$X_{2i} = \frac{V(\beta N - nN^2 + \beta nT - \beta NT - \beta nNT + nN^2T)}{nT^2(nN^2-2\beta N+\beta)}$$

$$\frac{\partial X_{2i}}{\partial N} = \frac{(1+T(n-1))(nN(N-2)+\beta)\beta V}{nT^2(nN^2-2N+1)^2}. \quad \text{(A19.2)}$$

If $\beta = 0$, then the numerator reduces to zero. However, if $\beta > 0$ then the numerator is positive, as $N \geq 2$, and $n \geq 2$. The denominator is always positive. Thus, we have:

$$\frac{\partial X_{2ij}}{\partial N} \geq 0, \quad \text{if } \beta \geq 0. \quad \square$$

Claim A2c. $\partial X_{ij}/\partial N \leq 0$ if $0 \leq \beta \leq 1$; but if $\beta > 1$ then $\partial X_{ij}/\partial N > 0$.

Proof.

$$\frac{\partial X_{ij}}{\partial N} = \frac{\partial (X_{1ij} + X_{2ij})}{\partial N}. \quad \text{(A20)}$$

$$\frac{\partial X_{ij}}{\partial N} = -\frac{(1-\beta)(1+T(n-1))(nN(N-2)+\beta)V}{nT^2(nN^2-2N+1)^2}. \quad \text{(A21)}$$

The denominator is always positive. The numerator will remain positive as long as $\beta \in [0,1)$. When $\beta = 1$ then the numerator becomes zero. However, if $\beta > 1$ then the numerator takes a negative value. Hence, $\partial X_{ij}/\partial N \leq 0$ if $0 \leq \beta \leq 1$. However, $\partial X_{ij}/\partial N > 0$ if $\beta > 1$. $\square$

Section A.3

Claims related to the intuition for Proposition 1 are proved in this section.

Claim A3a. $\partial X_{2ij}/\partial X_{1ij} \leq 0$ if $\beta \geq 0$.

Proof. From (A11), we have:

$$X_{2i} = \frac{V(T-1)}{nT^2} - \beta X_{1i}$$

$$\frac{\partial X_{2ij}}{\partial X_{1ij}} = -\beta. \quad \text{(A22)}$$

Thus, $\partial X_{2ij}/\partial X_{1ij} \leq 0$ if $\beta \geq 0$. $\square$

Claim A3b. $\partial X_{2ij}/\partial N = \beta\left|\partial X_{1ij}/\partial N\right| \geq 0$, if $\beta \geq 0$.

Proof. From (A20), we know that:

$$\frac{\partial X_{2i}}{\partial N} = \beta\left(\frac{(1+T(n-1))(nN(N-2)+\beta)V}{nT^2(nN^2-2N+1)^2}\right). \quad \text{(A23)}$$

From (A19), we have:

$$\left|\frac{\partial X_{1ij}}{\partial N}\right| = \frac{(1+T(n-1))(nN(N-2)+\beta)V}{nT^2(nN^2-2N+1)^2}. \quad \text{(A24)}$$

Hence it follows that:

$$\frac{\partial X_{2ij}}{\partial N} = \beta\left|\frac{\partial X_{1ij}}{\partial N}\right| \geq 0, \quad \text{if } \beta \geq 0. \quad \square$$

Section A.4. Effects of Number of Technology Paths (Proposition 2)

We prove below the three claims included in Proposition 2.

Claim A4a. $\partial X_{1ij}/\partial T < 0$ if $\beta < nN^2/2N-1$.

Proof. From Lemma A1, we have:

$$X_{1ij} = \frac{(N-1)(1-T+nT)V}{nT^2(nN^2-2\beta N+\beta)}$$

$$\frac{\partial X_{1ij}}{\partial T} = -\frac{(N-1)(2+(n-1)T)V}{(nN^2-2N\beta+\beta)T^3}. \quad \text{(A25)}$$

As $N \geq 2$ and $n \geq 2$, the numerator is positive. The denominator is positive as

$$\beta < \frac{nN^2}{2N-1}.$$

Thus, we have:

$$\frac{\partial X_{1ij}}{\partial T} < 0. \quad \square$$

Claim A4b. $\partial X_{2ij}/\partial T > 0$, if

$$T < T^* = \frac{2N(nN-\beta)}{n(\beta - N\beta + N^2) - N\beta}.$$

Proof. Lemma A2 gives the total joint investment in market development made by network j that holds the patent for technology i. On differentiating this joint investment with respect to T, we get:

$$\frac{\partial X_{2ij}}{\partial T} = \frac{NV\beta(T-2) + nV(T\beta(N-1) - N^2(T-2))}{nT^3(nN^2 + \beta - 2N\beta)}. \quad \text{(A26)}$$

The sign of the comparative static becomes positive, if:

$$T < T^* = \frac{2N(nN-\beta)}{n(\beta - N\beta + N^2) - N\beta}. \quad \text{(A27)}$$

Hence, $\partial X_{2ij}/\partial T > 0$, if $T < T^* = (2N(nN-\beta))/(n(\beta - N\beta + N^2) - N\beta)$. □

Claim A4c. $\partial X_{ij}/\partial T < 0$.

Proof. This comparative static is given by the sum of (A25) and (A26). On simplifying, we obtain:

$$\frac{\partial X_{ij}}{\partial T} = \big[V\big(2 - nN^2(T-2) + T(n - n\beta - 1) + N\big(T(1 + n(\beta-1) + \beta) - 2(1+\beta)\big)\big)\big] / [nT^3(nN^2 + \beta - 2N\beta)]. \quad \text{(A28)}$$

Note that $\partial^2 X_{ij}/\partial T^2 > 0$. On evaluating (A28) at T^* (A27):

$$\frac{\partial X_{ij}}{\partial T} = -\frac{V(N-1)(N\beta - n(N^2 + \beta - N\beta))^2}{4N^3(nN-\beta)^3}. \quad \text{(A29)}$$

We know that

$$\beta < nN \quad \text{as } \beta < \frac{nN^2}{2N-1} = nN\left(\frac{N}{2N-1}\right) < nN.$$

Consequently, the denominator is positive. The numerator is positive as $N \geq 2$. Hence, we have:

$$\frac{\partial X_{ij}}{\partial T} < 0. \quad \square$$

Section A.5. Effects of Market Sensitivity to Investments in Product Development (Proposition 3)

Claim A5a. $\partial X_{1ij}/\partial \beta > 0$.

Proof. From Lemma A1, we know that:

$$X_{1ij} = \frac{(N-1)(1 - T + nT)V}{nT^2(nN^2 - 2\beta N + \beta)}.$$

Therefore,

$$\frac{\partial X_{1ij}}{\partial \beta} = \frac{(N-1)(2N-1)(1 - T + nT)V}{nT^2(nN^2 - 2\beta N + \beta)^2}. \quad \text{(A30)}$$

The numerator is positive as $N \geq 2$. The denominator is always positive. Thus, $\partial X_{1ij}/\partial \beta > 0$. □

Claim A5b. $\partial X_{2ij}/\partial \beta < 0$.

Proof. From Lemma A2, we have:

$$X_{2i} = \frac{V(\beta N - nN^2 + \beta nT - \beta NT - \beta nNT + nN^2T)}{nT^2(nN^2 - 2\beta N + \beta)}$$

$$\frac{\partial X_{2i}}{\partial \beta} = -\frac{VN^2(N-1)(1 - T + nT)}{T^2(nN^2 - 2\beta N + \beta)^2}. \quad \text{(A31)}$$

As $N \geq 2$, $\partial X_{2ij}/\partial \beta < 0$. □

Claim A5c. $\partial X_{ij}/\partial \beta < 0$.

Proof. We know that:

$$\frac{\partial X_{ij}}{\partial \beta} = \frac{\partial (X_{1ij} + X_{2i})}{\partial \beta}. \quad \text{(A32)}$$

Using Lemma A1 and A2, and then simplifying we get

$$\frac{\partial X_{ij}}{\partial \beta} = -\frac{(N-1)(1 - 2N + nN^2)(1 - T + nT)V}{nT^2(nN^2 - 2\beta N + \beta)^2}.$$

The denominator is positive. The numerator is positive as $N \geq 2$, and $n \geq 2$. So we have:

$$\frac{\partial X_{ij}}{\partial \beta} < 0. \quad \square$$

Section B. Joint Product Development and Individual Market Development

Section B.1. Lemmas B1 and B2

In this section we prove these two lemmas that will be used later to prove Proposition 4, and the effects of T, N, and β.

Lemma B1.

$$X_{1ij} = \frac{V(N-1)}{n^2T^2(N^2 - 2N\beta + \beta)}. \quad \text{(B1)}$$

Proof. The probability of player k developing the market for technology i winning the second stage of the competition is given by:

$$p_{ik} = \frac{U_{ik}}{\sum_{l=1}^{T}\sum_{s=1}^{n} U_{ls}}, \quad \text{(B2)}$$

where

$$U_{ik} = \beta X_{1i} + x_{2ik}. \quad \text{(B3)}$$

X_{1i} is the joint investment made in developing the product in the first stage of the game by the network that won the patent for technology i, while x_{2ik} is the investment made by player k in the second stage of the game toward developing the market for the product based on technology i.

Let Π_{2ik} be the expected payoff in the second stage of the game for partner k in the network that won the patent for technology i:

$$\Pi_{2ik} = p_{ik}(V) - x_{2ik}. \quad \text{(B4)}$$

$$\Pi_{2ik} = \left(\frac{\beta X_{1i} + x_{2ik}}{\sum_{l=1}^{T}\sum_{s=1}^{n}(\beta X_{1l} + x_{2ls})}\right)V - x_{2ik}. \quad \text{(B5)}$$

$$\frac{\partial \Pi_{2ik}}{\partial x_{2ik}} = -1 + \frac{V\sum_{l=2}^{T}\sum_{s=1}^{n}(\beta X_{1l} + x_{2ls})}{\left(\sum_{l=1}^{T}\sum_{s=1}^{n}(\beta X_{1l} + x_{2ls})\right)^2} = 0. \quad \text{(B6)}$$

We have an interior maximum for x_{2ik}, as Π_{2ik} is concave in x_{2ik}:

$$\frac{\partial^2 \Pi_{2ik}}{\partial x_{2ik}^2} = -\frac{2V\sum_{l=2}^{T}\sum_{s=1}^{n}(\beta X_{1l} + x_{2ls})}{\left(\sum_{l=1}^{T}\sum_{s=1}^{n}(\beta X_{1l} + x_{2ls})\right)^3} < 0. \quad \text{(B7)}$$

Since the networks are symmetric, $\sum_{l=2}^{T}\sum_{s=1}^{n}(\beta X_{1l} + x_{2ls}) = n(T-1)U_i$. On simplifying B7, we obtain:

$$U_i = \frac{V\,(nT-1)}{n^2T^2}. \quad \text{(B8)}$$

On replacing (B8) in (B2), we find that the probability of any network winning the second stage of the competition is $1/(nT)$. Therefore, the expected profit from winning the second stage of the game is:

$$\Pi_{2ik} = \frac{1}{nT}V - x_{2ik}. \tag{B9}$$

From (B3) and (B8) we know that:

$$\beta X_{1i} + x_{2ik} = \frac{V(nT-1)}{n^2T^2}. \tag{B10}$$

$$x_{2ik} = \frac{V(nT-1)}{n^2T^2} - \beta X_{1i}. \tag{B11}$$

The probability that network j wins the patent for technology i in the first stage of the competition is:

$$p_{1ij} = \frac{U_{1ij}}{\sum_{m=1}^{N} U_{1ij}}. \tag{B12}$$

Let Π_{1ijk} be the first stage expected payoff to player k in network j developing a product based on technology i.

$$\Pi_{1ijk} = -x_{1ijk} + p_{1ij} \cdot \Pi_{2ik}. \tag{B13}$$

On substituting (B9) and (B12) in (B13) and simplifying we obtain:

$$\Pi_{1ijk} = -x_{1ijk} + \frac{\left(x_{1ijk}+\sum_{s=2}^{n} x_{1ijs}\right)\left(V/n^2T^2+\beta\left(x_{1ijk}+\sum_{s=2}^{n} x_{1ijs}\right)\right)}{\left(\sum_{m=2}^{N} U_{1im}+x_{1ijk}+\sum_{s=2}^{n} x_{1ijs}\right)}. \tag{B14}$$

$$\frac{\partial \Pi_{1ijk}}{\partial x_{1ijk}} = -1+\beta+\frac{\sum_{m=2}^{N} U_{1im}\left(V-\beta n^2T^2\sum_{m=2}^{N} U_{1im}\right)}{n^2T^2\left(\sum_{m=2}^{N} U_{1im}+x_{1ijk}+\sum_{s=2}^{n} x_{1ijs}\right)^2} = 0. \tag{B15}$$

As the networks and players are symmetric, $\sum_{m=2}^{N} U_{1im} = (N-1)X_{1ij}$ and $\sum_{s=2}^{n} x_{1ijs} = (n-1)x_{1ijk}$. In (B15), if we replace $x_{1ijk}+\sum_{s=2}^{n} x_{1ijs}$ with X_{1i}, and then solve for X_{1i} we get:

$$X_{1ij} = \frac{V(N-1)}{n^2T^2(N^2-2N\beta+\beta)}. \quad \square$$

Lemma B2.

$$x_{2ik} = \frac{V(nN^2T+N\beta+nT\beta-N^2-2nNT\beta)}{n^2T^2(N^2+\beta-2N\beta)}. \tag{B16}$$

Proof. We know from (B11):

$$x_{2ik} = \frac{V(nT-1)}{n^2T^2} - \beta X_{1i}.$$

On using Lemma B1 and simplifying the expression, we obtain:

$$x_{2ik} = \frac{V(nN^2T+N\beta+nT\beta-N^2-2nNT\beta)}{n^2T^2(N^2+\beta-2N\beta)}. \quad \square$$

Section B.2. Effects of Individual Development of Market (Proposition 4)

Claim B2a. The first claim of Proposition 4 is that individual development of market decreases investments in product development if $0 \le \beta \le 1$.

Lemma A1 provides the equilibrium joint investment in product development, if players jointly develop the market:

$$X_{1ij} = \frac{V(N-1)(nT-T+1)}{nT^2(nN^2-2N\beta+\beta)}.$$

Similarly, from Lemma B1 we know the equilibrium joint investment in product development, if players individually develop the market:

$$X_{1ij} = \frac{v(N-1)}{n^2T^2(N^2-2N\beta+\beta)}.$$

Therefore, on subtracting (A1) from (B1) and simplifying, we have:

$$\Delta_1^I = -\frac{V(n-1)(N-1)(nNT(N-2\beta)+\beta(nT+1-2N))}{n^2T^2(N^2+\beta-2N\beta)(nN^2+\beta-2N\beta)}. \tag{B17}$$

This expression will remain negative if

$$n > n^* = \frac{(2N-1)\beta}{T(N^2+\beta-2N\beta)}.$$

The value of n^* increases in β. So the expression would be negative if

$$n^* = \frac{(2N-1)}{T(N-1)^2}.$$

As $N \ge 2$, the value of n^* is highest when $N=2$, and corresponding value of $n^* = 3/T$. As $T \ge 2$ and $n \ge 2$ this condition will always be met. Hence the expression in (B17) is negative. Thus, $\Delta_1^I < 0$. $\square$

Claim B2b. The second claim of Proposition 4 is that individual development of market increases investments in market development, if $0 \le \beta \le 1$.

Lemma A2 provides the equilibrium joint investment in market development, if players jointly develop the market (A18):

$$X_{2ij} = \frac{V(\beta N - nN^2 + \beta nT - \beta NT - \beta nNT + nN^2T)}{nT^2(nN^2-2\beta N+\beta)}.$$

In Lemma B2 we have the equilibrium joint investment in market development, if players individually develop the market (see B16).

$$x_{2ik} = \frac{V(nN^2T+N\beta+nT\beta-N^2-2nNT\beta)}{n^2T^2(N^2+\beta-2N\beta)}.$$

Therefore, on subtracting (A18) from (B16), we have:

$$\Delta_2^I = \frac{(n-1)V(n(N^2+\beta-2N\beta)(N^2+T\beta(N-1))-N\beta(2N-1)(N-\beta))}{n^2T^2(N^2+\beta-2N\beta)(nN^2+\beta-2N\beta)}. \tag{B18}$$

This expression will be positive if

$$n > n^* = \frac{N\beta(N-\beta)(2N-1)}{(N^2+T\beta(N-1))(N^2+\beta-2N\beta)}. \tag{B19}$$

Note that the value of n^* is increasing in β. The expression would remain positive if:

$$n > n^* = \frac{N(2N-1)}{(N^2+T(N-1))(N-1)}. \tag{B20}$$

As the value of n^* is decreasing in N and the lowest value of N is 2, the condition will be satisfied if:

$$n > n^* = \frac{6}{4+T}. \tag{B21}$$

As $T \ge 2$ and $n \ge 2$ this condition will always be satisfied. Hence, $\Delta_2 > 0$. $\square$

Claim B2c. The last claim of Proposition 4 is that individual development of market increases the total investments in product and market development.

Lemma A1 and Lemma A2 provide the equilibrium joint investment in product and market development, if players jointly develop the market, whereas Lemma B1 and Lemma B2 give the equilibrium joint investment in product development and the investment in market development, if players individually develop the market.

On subtracting the sum of (A1) and (A18) from the sum of (B1) and (B16), we have:

$$\begin{aligned}\Delta^I = V\Big[&\big(N^2(nT-1)+nT\beta+N(1+\beta-2nT\beta)-1\big)\big/(N^2+\beta-2N\beta)\\ &-\big(n\big(nN^2(T-1)+T+nT(\beta-1)+N(1+\beta\\ &\quad -T(1+n(\beta-1)+\beta))\big)\big)\big/\big(nN^2+\beta-2N\beta\big)\Big]\Big/(n^2T^2).\end{aligned} \tag{B22}$$

This expression is positive if:

$$n > n^* = \frac{(2N-1)\beta(1+N^2-N(1+\beta))}{(N^2+\beta-2N\beta)(N^2+T-T(N(1-\beta)+\beta))}. \tag{B23}$$

As n^* is increasing in β, the expression would remain positive if:

$$n > n^* = \frac{(2N-1)}{N^2}.$$

As $N \geq 2$, and $n \geq 2$ this condition will always be satisfied. Hence, $\Delta^I > 0$. □

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