Collaborating to Compete

A Game-Theoretical Model and Empirical Investigation of the Effect of Profit-Sharing Arrangement and Type of Alliance

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Abstract

In collaborating to compete, firms forge different types of strategic alliances: same function alliances (e.g., R&D alliance), cross-function alliances (e.g., marketing and production alliance), and even parallel development of new products. A major challenge in the management of these alliances is how to control the resource commitment of partners to the collaboration. In this research we examine, both theoretically and empirically, how the type of an alliance and the prescribed profit-sharing arrangement affect the resource commitments of partners. We model the interaction within an alliance as a noncooperative variable-sum game, in which each firm invests part of its resources to increase the utility of a new product offering. Different types of alliances are modeled by varying how the resources committed by partners in an alliance determine the utility of the jointly-developed new product. We then model the inter-alliance competition by nestling two independent intra-alliance games in a super game in which the groups compete for a market. The partners of the winning alliance share the profits in one of two ways: equally or proportionally to their individual investments. The Nash equilibrium solutions for the resulting games are investigated.

In the case of same-function alliances, when the market is large the predicted investment patterns under both profit sharing rules are comparable. Partners developing new products in parallel, unlike the partners in a same function alliance, commit fewer resources to their alliance. However, the profit-sharing arrangement matters in such alliances -- partners commit more resources when profits are shared proportionally rather than equally.

We test the predictions of the model in two laboratory experiments in which subjects played the inter-alliance competition game for a monetary payoff contingent on performance. The experimental results provide strong support for the theoretical model. A new analysis of Robertson and Gatignon's (1998) field survey data on the conduct of corporate partners in technology alliances validates our model of same-function alliances.

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1. Introduction

Given the complexity of developing and marketing new technology products, firms are increasingly finding it advantageous to “collaborate to compete” in the marketplace (e.g., Bucklin and Sengupta 1993, Gomes-Casseras 1994, Harrigan 1988, Yoshino and Rangan 1995). In collaborating to compete, firms forge different types of alliances: same-function alliances, cross-functional alliances, and even parallel development of new products. Hence, we see GM and Suzuki pooling their technological resources to manufacture cars, Siemens and Corning forming a cross-functional alliance to produce and market fiber-optic cables, and Intel and AMD developing research products in parallel to be shared by both partners.

Although alliances offer the potential benefit of allowing firms to pool resources, they also carry an ancillary risk: in exchange for the potential improvement in skills and resources, the firm forgoes its ability to control its own destiny in the marketplace. Specifically, a firm’s success now becomes contingent on the willingness of its partners to commit their best skills and resources to the venture — a commitment over which the firm has no direct control. A major challenge faced by alliances is thus to identify mechanisms that minimize the risk of under-commitment by partners.

While the study of strategic alliances forms a growing part of the literature in management strategy and marketing, surprisingly little work has focused on how type of alliance and profit-sharing arrangements affect the commitment of partners (Blodgett 1992). Researchers have examined such issues as the factors influencing the formation and stability of alliances (e.g., Bucklin and Sengupta 1993; Franko 1971, Killing 1982 and 1983, Stuckey 1983, Beamish 1985, and Kogut 1988), how alliances encourage inter-organizational learning and efficiency (e.g., Hamel 1991; Stuckey 1983), how industries get concentrated as available for our analysis.
a consequence of the growth of alliances (e.g., Berg and Friedman 1980, Pfeffer and Nowak 1976), and how partnering firms protect their intellectual properties (e.g., Dutta and Weiss 1997). More recently marketing researchers have experimentally investigated the effect of co-branding alliances on transfer of goodwill across partnering brands (Park et al 1996). Yet, the factors that influence the commitment of resources by individual partners are not as well understood.

To illustrate, a conventional wisdom of alliance managers is that equal sharing of ownership and profits provides incentives for firms to free-ride, and hence will often lead to the failure of alliances (Bleeke and Ernst 1991, Mody 1993). Is this the case? What little data exist on this issue says that the reality might be just the opposite. A 1991 McKinsey survey (Bleeke and Ernst 1991) found that alliances in which partners share profits equally are, in fact, more likely to succeed (60%) than alliances in which partners share the profits not equally but in proportion of their investments (31%). Yet, how general this result might be or what mechanisms evoke such an outcome is not clear.

The purpose of this work is to take an initial step toward understanding how profit-sharing arrangement and type of alliance affect the resource commitment of a partner. Specifically, we first propose a game-theoretical model of competition among alliances that allows us to investigate the effect of profit-sharing arrangement and type of alliance on the resource commitments of alliance partners. We then examine how well the actual resource commitments conform to the model predictions. We report the results of two tests: a controlled laboratory test and a cross-sectional field test.

A central theoretical result is that when a market is large, both equal and proportional sharing of profits will induce similar investment patterns in same-function alliances such as R&D alliances. This result implies that given a sufficiently large market, collaborators who

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1 The reported figures on the stability of joint ventures vary widely: 24.1% (Franko 1971), 30% (Killing 1882,
share the profits equally need not monitor each partner's inputs. In contrast, the profit-sharing arrangement does matter when partners develop a new product in parallel. Here, equal profit sharing reduces the inputs of partners. Further, the type of alliance also affects the resources committed by partners to the joint endeavor. Partners developing products in parallel, unlike the partners in a same-function alliance, commit fewer resources to their alliance.

The empirical evidence suggests that actual resource-commitment decisions respond to changes in alliance structures in a way that closely conforms to these normative predictions. Specifically, the laboratory experiments show that actual resource allocations closely track the point predictions of normative theory in most cases, and directional support is offered by the field survey. The theory seems to under-predict resource commitments in experimental settings where market demand is low. Such a departure from game-theoretic prediction has been observed repeatedly by experimental researchers (e.g., Dawes 1980, Dawes and Thaler 1988, Cooper et al. 1996).

The rest of the paper is organized as follows. In Section 2 we develop the model. Later in Section 3, we analyze the implications of the model for same-function alliances and parallel development of products. Section 4 reports the results of two laboratory studies designed to test the model. Section 5 discusses a preliminary field test. We conclude in Section 6 by outlining directions for further research.

2. Model Development

Consider two alliances, \( i \) and \( j \), which are competing to develop a new technology product. The development of this product requires substantial resources (capital, human, technology, etc.). No single firm has sufficient resources to competitively develop the new technology product without the support of its partners. Denote the number of partners in alliances \( i \) and \( j \) by \( n_i \) and \( n_j \), respectively. The number of firms in each alliance is known to

1983), 42% (Stuckey 1983), 45% (Beamish 1985), 50% (Reynolds 1984) and 46.3% (Kogut 1988).
all players. Each firm has only a limited amount of capital to invest in the project. This limitation may be due to the financial constraints placed by the capital markets. Denote the maximum investment capital of firm $k$ in alliance $i$ by $c_{ik}$ and that of firm $l$ in alliance $j$ by $c_{jl}$. We assume that the investment capital of each partner in the competing alliances is equal (i.e., $c_{ik} = c_{jl} = c \forall k, l$). Further, the value of $c$ is common knowledge.

Partners in an alliance invest in alliance-specific assets to render the focal relationship productive (Williamson 1985). But alliance-specific assets have limited mobility and little residual value outside the alliance. An all-pay auction captures an important feature of strategic alliances: the unconditional commitment of resources to win the competition (Shubik 1971, Gilbert and Newberry 1982, O’Neill 1986, Leiningen 1989, Rapoport and Amaldoss 1996). We use an all-pay auction to model the competition among alliances for developing a new product. Assume that each partner invests part of its available resources in the collaborative project. Denote the actual investment of partner $k$ ($l$) in alliance $i$ ($j$) by $I_{ik}$ ($I_{jl}$). The investment made by each firm for developing the new technology product is constrained only by the available capital (i.e., $0 \leq I_{ik} \leq c$ and $0 \leq I_{jl} \leq c$). After each firm contributes to the project, its investment is translated into an alliance-specific asset. Therefore, regardless of the outcome of the inter-alliance competition, each firm’s investment is sunk and non-recoverable.

We assume that the value or utility which consumers associate with the new product developed by alliance $i$, $U(i)$, depends on the magnitude of the investments made by the partners in the alliance. We consider three different types of alliances: same-function alliances such as R&D alliances, cross-functional alliances such as marketing and production alliances, and parallel development of products.
1) We model a same-function alliance by allowing the utility of the new product developed by the alliance to be determined by the sum of the inputs of the partners. This implies that the firms’ inputs combine in a compensatory fashion.

2) Sometimes partners develop a new product in parallel by pursuing alternative technological paths. The firm successfully developing the product shares the patents with its partners. The spirit of such a parallel development process is captured by allowing the utility of the new product to be determined by the maximum individual input of the partners in an alliance. Note that the inputs are not compensatory.

3) Partners in a cross-functional alliance add value to the new product serially. A cross-functional alliance resembles a chain, which is only as strong as its weakest link. We model such an alliance by allowing the utility of the new product to be determined by the minimum individual input of the partners in an alliance.

Formally, the utility of the new product developed by alliance $i$, $U(i)$ is given by

$$
U(i) = \begin{cases} 
\sum_{k=1}^{n} I_k, & \text{if alliance } i \text{ is a same-function alliance.} \\
\text{Max}\left\{I_1, \ldots, I_a, \ldots, I_k\right\}, & \text{if products are developed in parallel} \\
\text{Min}\left\{I_1, \ldots, I_a, \ldots, I_k\right\}, & \text{if alliance } i \text{ is a cross-functional alliance}
\end{cases}
$$

Similarly, we define the utility of the new product developed by the partners in alliance $j$, $U(j)$.

In the inter-alliance competition, the alliance whose partners develop a better product wins the competition, meaning that all consumers choose the better product. The winning alliance captures a product market of known and fixed size $m$. Alternatively, we allow the realized value of market increase as the investments increase. In other words, the potential
value of the market is fixed, but the realized value depends on the collective investments of alliance partners. In the event that both alliances develop products offering the same level of utility, each alliance gets a reward of \( s \) \((0 \leq s \leq m/2)\).

Sometimes partners in an alliance receive benefits that go beyond a share of the market at stake. For example, the new product may offer synergy to the existing product portfolio. In our model we allow alliance partners to receive such a side benefit regardless of the outcome of the competition. The maximum value of the side benefit or good, \( g \) \((g \geq 0)\), that a partner can possibly get is known and fixed. But the actual value of the side benefit, \( G(i) \), which each partner realizes is contingent on the extent to which the new technology product is developed (or the investments which partners in the alliance make in the new technology product). Formally, we define \( G(i) \) as shown in Equation 2.

\[
G(i) = \begin{cases} 
    g \left( \frac{\sum_{k=1}^{n_i} I_{i,k}}{c_{i,k}} \right), & \text{if alliance } i \text{ is a same-function alliance.} \\
    g \left( \frac{\max \left\{ I_{i,1}, \ldots, I_{i,k}, \ldots, I_{i,m} \right\}}{c_{i,k}} \right), & \text{if products are developed in parallel} \\
    g \left( \frac{\min \left\{ I_{i,1}, \ldots, I_{i,k}, \ldots, I_{i,m} \right\}}{c_{i,k}} \right), & \text{if alliance } i \text{ is a cross-functional alliance}
\end{cases}
\]

(2)

Similarly, we define \( G(j) \). In some instances the new product may not offer any side benefit; in such cases we set \( g = 0 \).

In light of Equations (1) and (2), if alliance \( i \) wins the competition, then it gets both \( m \) and \( G(i) \). On the other hand, if alliance \( i \) loses, it gets only \( G(i) \). Thus, this inter-alliance game need not be a winner-take-all game. Yet, consistent with the traditional R&D literature, the
market for new product is assumed to be taken completely by the winning alliance (e.g., Gilbert and Newberry, 1982).

This non-cooperative n-person game ($n = n_i + n_j$) with simultaneous moves is assumed to be played once\(^2\). When the players in a non-cooperative game make their decisions simultaneously, they cannot condition their decisions on the behavior of their partners. In other words, a member of the alliance cannot monitor the behavior of its partner and use that information in making its decision. Thus, a non-cooperative game with simultaneous moves captures the essential features of the behavioral uncertainty faced by the partners in an alliance.

Ideally, partners would like to accurately measure the resources committed by each partner and share the profits in proportion to their investments. But precisely evaluating the resource commitment by each partner in an alliance is difficult, especially when partners share intellectual properties and tacit knowledge (Kogut 1988). Sharing profits equally circumvents the need to monitor the inputs of alliance partners, but it poses the serious threat of free riding. Our model allows for equal, as well as proportional, profit sharing. We use this model to understand whether, and if so when, equal profit sharing would induce behavior comparable to proportional profit sharing.

The parameters $n_i$, $n_j$, $c$, $U(i)$, $U(j)$, $g$, $m$, $s$ and the profit-sharing arrangement are all assumed to be common knowledge.

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\(^2\) The partners in an alliance join together with the expressed intention of cooperating to win a competition. These partners need to cooperate in the presence of strong incentives to act otherwise (Pisano, Russo, and Teece 1988, Hamel 1991, Mody 1993). For instance, a partner can distort the transfer price of its inputs for the joint venture or shirk its responsibility to provide intellectual properties and knowledge, especially when it is difficult to monitor such behavior. Although the joint-venture agreements typically detail the profit-sharing rules and specify procedures for administrative control, they do not specify \textit{ex ante} the performance of the partners in the alliance (Harrigan 1988, Kogut 1988). Therefore, there is often uncertainty about the behavior of the partners and strong incentive to free ride. The inherent incompleteness of joint-venture agreements, the notorious difficulty in enforcing contractual agreements between members of alliances, and the potential for conflict among the partners in an alliance make it appropriate to model such situations as non-cooperative games.
In sum, the model captures two key facets of strategic alliances: alliance-specificity of investments and behavioral uncertainty. The model can be used to investigate both theoretically and experimentally how the type of alliance and profit-sharing arrangement affect the investment behavior of partners.

3. Analysis of the Model

**Overview.** In this section we examine theoretically the effects of profit-sharing arrangement in different types of alliances. Specifically, we ask the question: what should be the investment pattern of alliance partners conditional on type of alliance and profit-sharing arrangement?. We first examine the case of same-function alliance. In general terms, two levels of interaction are involved in this competition between alliances. Each firm is engaged in an independent intra-alliance conflict with its partner. Then the partners in an alliance are jointly engaged in an inter-alliance competition. In our analyses, we first discuss the intra-alliance competition, and later examine the inter-alliance competition \( (n_i = n_j = 2) \). Interestingly, seventy nine percent of the technology alliances surveyed by Robertson and Gatignon (1998) involved only two partners. We limit the strategy space of partner \( k \) in alliance \( i \) to three levels: low or zero investment, middle or half-hearted investment, and high or full investment. This restriction to three investment levels, which can be relaxed, keeps the decision problem cognitively simpler and more amenable to a rigorous experimental investigation (e.g., Smith 1962 and 1982, Rapoport 1987, Rapoport and Bornstein 1987, Mookherjee and Sopher 1997).

**Case 1: Same-function alliances.** We model the same-function alliance by allowing the utility of the new product developed by the alliance to be determined by the sum of the inputs of the partners (Equation 1).

**The Intra-alliance Conflict.** The intra-alliance conflict is modeled as a non-cooperative two-person game in strategic form. The payoffs associated with the resolution of the intra-
alliance conflict involving the two players in alliance \( i \), player \( i_1 \) and player \( i_2 \), is presented in strategic form in the upper part of Table 1. Thus, for example, if player \( i_1 \) invests \( c/2 \) and player \( i_2 \) invests \( c \), then for the same-function alliance \( G(i) = g[(c/2 + c)/2c] = 3g/4 \) (Equation 2), and the payoffs for players \( i_1 \) and \( i_2 \) are \( 3g/4 - c/2 \) and \( 3g/4 - c \), respectively.

When the investment capital, \( c \), and the maximum side benefit, \( g \), satisfy the inequality \( 2c > g \), the strategy of investing \( 0 \) dominates the strategy of investing \( c/2 \), and the latter strategy, in turn, dominates the strategy of investing \( c \). Therefore, the equilibrium pair of strategies for this two-person game is \((0, 0)\). If we impose the additional condition that the side benefit, \( g \), exceeds the investment capital (i.e., \( g > c \)), then it is easy to verify that the intra-alliance conflict is a \( 3 \times 3 \) Prisoner’s Dilemma game. Under this condition, if the side benefit exceeds the aggregate investment capital of the partners in an alliance (i.e., the inequality \( 2c > g \) is violated), then the equilibrium pair of strategies is \((c, c)\), and each alliance partner should invest his maximum.

--------- Insert Table 1 ---------

*The Inter-alliance Competition.* Next, we embed the two independent intra-alliance conflicts in an inter-alliance competition for the market. The two alliances, \( i \) and \( j \), compete with each other for a market of known and fixed size \( m \). The alliance that invests more in improving the utility of the product develops a better product. All the consumers choose the better product and consequently the winner takes the entire market. Partners in the losing alliance lose their alliance-specific investments and receive no share of the market. In the case of a tie, which can arise when the strategy spaces are assumed to be discrete, each alliance receives \( s \) units, where \( 0 \leq s \leq m/2 \).

Consider first equal profit-sharing agreements, where a fixed market \( m \) is shared equally among the members of the winning alliance. Denote the total investment of alliances \( i \)
and \( j \) by \( T_i \) and \( T_j \) respectively. In our case where each strategy space includes only three elements, \( T_i = T_j = \{0, c/2, c, 3c/2, 2c\} \). The middle panel of Table 1 portrays the inter-alliance competition as a non-cooperative two-person game in which each alliance has five pure strategies.

We impose the condition \( m > 2c - g \). This implies that the market size, \( m \), is greater than the net cost, \( 2c - g \), of participating in the inter-alliance competition. This condition ensures that there is an incentive for each alliance to consider participating in the game.

Two alternative rules for breaking ties seem reasonable. First, consider the option of setting \( s = 0 \) in case of a tie, implying that both alliances make no incremental profit in case of a tie. This stipulation is tenable if the competing alliances constitute a duopoly. In such instances, if the competing alliances introduce similar products, they may compete away all potential profits. Alternatively, we consider setting \( s = m/2 \) in case of ties, implying that both alliances share the market if they introduce the new product simultaneously.

**Lemma 1:** The inter-alliance competition between two same-function alliances has only a mixed strategy solution when \( s = 0 \) and \( m > 2c - g > 0 \).

**Proof:** See Appendix 1.1

The condition \( m > 2c - g \) implies that the size of the market exceeds the net cost of the alliance engaging in the competition. The stipulation \( 2c - g > 0 \) means that the net cost is positive.

Next, we consider the case \( s = m/2 \), where the competing alliances share the market if their new products offer comparable utilities.

**Lemma 2:** The inter-alliance competition between two same-function alliances has only a mixed strategy solution if \( s = m/2 \) and \( 4c > m > 2c - g > 0 \).

**Proof:** See Appendix 1.2
The condition $4c > m$ implies that the total costs incurred by the two competing alliances exceeds the value of the market. If the total costs were smaller than the market size, then each of the players could invest $c$ and gain a quarter of the market ($m/4$) despite no alliance winning this competition. The meaning of $m > 2c - g > 0$ has been discussed previously.

To construct the mixed strategy solution we proceed as follows. Denote the probability of a player investing 0, $c/2$, and $c$ units of capital by $p_1$, $p_2$, and $p_3$, respectively. A mixed strategy in the context of this inter-alliance competition implies that there is no incentive to invest either $c$, $c/2$, or 0. If everyone else invests $c$, then there is an incentive to invest 0 or $c/2$. Similarly, if everyone else invests $c/2$, there is an incentive to invest 0 or $c$. Finally, if everyone else invests 0, there is an incentive to invest $c/2$ or $c$. However, if one firm mixes its three strategies according to the equilibrium solution, then there is no incentive for the other firm to depart from this action. This interpretation of the equilibrium solution is akin to that found in the sales promotion literature (e.g., Raju, Srinivasan, and Lal 1990).

**Lemma 3:** The mixed strategy equilibrium solution for a partner in a same-function alliance with equal profit-sharing arrangement is given by the solution to the following system of three equations:

\[
\begin{align*}
(s/2) \left( 2 p_1^2 p_2 + p_2^3 + 2 p_1 p_2 p_3 + 2 p_2 p_3^2 - p_1^3 - 2 p_1 p_2^2 - p_2^2 p_3 \right) \\
- 2 p_1 p_3^2 + (g/2) (p_2 - p_3) + (g/4) (p_1 - p_2) + (3g/4) p_3 \\
+ (m/2) (p_1^3 + 2 p_1 p_2^2 + p_2^2 p_3 + 2 p_1 p_3^2) = c/2, \\
\end{align*}
\]

\[
\begin{align*}
(s/2) \left( p_1 p_2^2 + 2 p_1^2 p_3 + p_3^3 - 2 p_1^2 p_2 - p_2^3 - 2 p_2 p_3^2 + 2 p_2^2 p_3 \right) \\
- 2 p_1 p_2 p_3 + (g/2) (p_1 - p_2) - (g/4) p_1 + (3g/4) (p_2 - p_3) + g (p_3) \\
+ (m/2) \left( 2 p_1 p_2 + p_2^3 + 2 p_2 p_3^2 - 2 p_1 p_2^2 \right) = c/2, \\
\end{align*}
\]

13
\[ p_1 + p_2 + p_3 = 1. \]  \hfill (5)

The parameters \( m, s \) and \( g \) in these three equations satisfy the constraints \( g > c, m/2 > c \), and \( 0 \leq s \leq m/2 \).

**Proof:** See Appendix 1.3.

The system of Equations (3), (4), and (5) does not have a closed form solution. We can solve it numerically in order to understand the behavior of the mixed strategy equilibrium solution over the desired parameter space. The following discussion is based on such an analysis.

**Effect of profit-sharing arrangement.** Consider first the effect of the equal profit-sharing arrangement and then compare it with the proportional profit-sharing arrangement.

**Equal profit-sharing arrangement.** We examine the case where partners agree to share profits equally. In such situations, firms have an opportunity to free ride on the efforts of their partners. When the size of the market, \( m \), increases in relation to the endowment, \( c \), the value of the endowment to market size ratio, \( c/m \), decreases and the reward for winning the competition increases. Figure 1A shows that as the reward for winning the competition increases, partners commit more resources to their collaborative endeavor: \( p(c) \) increases non-linearly in the reward, while \( p(c/2) \) and \( p(0) \) decrease as the reward increases.

--------- Insert Figure 1 ---------

The intuition behind the results displayed in Fig. 1A is that each partner faces a tension between the desire to win the inter-alliance competition and the inclination to free ride on the investments of the other partners of its alliance. As the market at stake gets larger, the desire of each partner to win the competition outweighs the tendency to free ride on the investments of its collaborators.
Proportional profit-sharing arrangement. Along the lines discussed in Lemma 3, we constructed a similar system of three equations for computing the mixed strategy equilibrium solution, when the partners of the winning alliance share their profit proportionally (See Appendix 1.4).

Figure 1B presents the mixed strategy equilibrium investment pattern when partners share the profit proportionally. We notice that as the size of the market increases the probability of investing the entire resource (c) increases, whereas the probabilities of investing \(c/2\) and \(0\) decrease. These three functions do not intersect.

Comparison of the profit-sharing arrangements. We are now in a position to understand whether, and if so when, equal profit sharing induces an investment pattern comparable to proportional profit sharing. Figure 1C shows what fraction of the available capital is invested under either profit-sharing arrangement. Although the equilibrium investment under equal profit-sharing arrangement is considerably smaller when the size of reward is low (or \(c/m\) is high), the difference between the two profit-sharing arrangements soon becomes negligible.

These observations are summarized below:

**Proposition 1:** When the market is large in relation to each partner’s endowment, the mixed strategy equilibrium investment patterns under both profit-sharing arrangements are similar. However, when the market is small, the level of investment under the proportional profit-sharing arrangement is greater than that under the equal profit-sharing arrangement.

The proportional profit-sharing arrangement helps to avoid free riding on the investments of collaborators. But this arrangement necessitates monitoring each partner’s inputs. It is sometimes difficult to monitor each firm’s contribution to the collaboration. The equal profit-sharing arrangement circumvents the need to closely monitor each firm’s contribution to the collaboration, though it poses the threat of free riding. Yet, when the
market is large, the motivation to win the competition keeps the desire to free ride in check. Thus, when the market is relatively large, firms can choose to share the profits equally placing confidence in market forces to discipline the behavior of their partners.³

Case 2: Parallel Development of New Products. We model the parallel development of new products by allowing the utility of the new product to be determined by the maximum input of an individual member of the alliance (Equation 1). As before, we limit the investment space of partner \( k \) in alliance \( i \) to three levels. Consequently, the utility of the product developed by alliance \( i \) is confined to three levels: \( U(i) = \{0, c/2, c\} \).

The value of the side benefit realized by a partner in alliance \( i \), \( G(i) \), is given in Equation (2). When developing a new product in parallel, partner \( k \) in alliance \( i \), is assured of realizing the full value of the side benefit, if it invests \( c \). In other words, if \( i_f = c \), then \( \max\{I_1, I_2\} = c \), and so \( G(i) = g \). Note that if \( g > c \), there is incentive for every partner to invest \( c \) even if the contested market is hardly worth anything. It is, therefore, more interesting to examine the case where the cost of developing the new technology exceeds the value of the side benefit, \( c > g \geq 0 \). The resulting intra-alliance conflict between players \( i_f \) and \( i_2 \) is presented in the lower panel of Table 1. The interpretation of the payoffs in each cell of the matrix is the same as that discussed in same function alliance. In this noncooperative two-person game, investing \( c/2 \) dominates investing \( c \), and investing \( 0 \) in turn dominates investing \( c/2 \). Thus, the equilibrium pair of strategies is \((0, 0)\).

The inter-alliance competition remains a two-person noncooperative game in strategic form (see middle panel of Table 1). The market at stake is greater than the net cost of developing the new product, \( m > 2c - g \). This implies that participating in the competition is attractive to the alliances. In this non-cooperative game, the alliance offering the better

³Using this model, we examined the effect of side benefit on the resource commitment of partners. Additionally, we also studied the effect of the market size not being fixed but contingent on the collective investments of partners in the competing alliances. The results are consistent with intuition.
product wins the competition. In case of a tie, each alliance gets a reward of size \( s \) (\( s = 0 \), or \( m/2 \)). The parameters \( g, m \) and \( s \) are assumed to be fixed and commonly known.

**Lemma 4:** When partners develop new products in parallel and agree to share profits equally, the inter-alliance game has a mixed strategy solution if \( m > 2c - g \), \( s = 0 \) and \( c > 0 \).

**Proof:** See Appendix 1.5

The condition that the value of the market at stake is more than the net cost of developing the product, \( m > 2c - g \), and the stipulation that cost is positive, \( c > 0 \), are quite reasonable. Next, we examine the implication of breaking a tie in the inter-alliance competition by letting each of the competing alliance get 50% of the market (\( s = m/2 \)).

**Lemma 5:** When \( s = m/2 \), the inter-alliance competition again has only a mixed strategy solution if \( 4c > m > 2c - g \).

**Proof:** See Appendix 1.6

If the market at stake is more than four times the cost of developing the product, \( (m > 4c) \), investing \( c \) assures each partner a 25% share of the market (\( m/4 \)). Thus, every partner will invest \( c \) when \( m > 4c \). We focus on cases where \( 4c > m \) and proceed to examine the mixed strategy equilibrium solution.

**Lemma 6:** The mixed strategy equilibrium for this inter-alliance competition, when partners share profits equally, is given by the solution to the following system of equations.

\[
\begin{align*}
(g/2 + m/2) p_1^3 & - (g/2) (p_1 + 2p_2) (2p_1 p_3 + 2p_2 p_3 + p_3^2) \\
+ p_1 (g/2 + s/2) (2p_1 p_2 + p_2^2) & - (s/2) p_1^3 = c/2. \\

(6)
\end{align*}
\]

\[
\begin{align*}
(g + m/2) (p_1^2 + p_1^2 p_3 + 2p_1 p_2 + p_2^2 - 2p_1 p_2 p_3 - p_2^2 p_3) \\
- (g/2 + m/2) (p_1^3 + p_1^2 p_2) & - (g/2) (p_1 + p_2) (2p_1 p_3 + 2p_2 p_3 + p_3^2) \\
- (g/2 + s/2) (2p_1^2 p_2 + p_1 p_2^2 - 2p_1 p_2^2 - p_2^2) \\
+ (g + s/2) p_3 (2p_1 p_3 + 2p_2 p_3 + p_3^2) & = c/2.

(7)
\end{align*}
\]
\[ p_1 + p_2 + p_3 = 1. \]  \hspace{1cm} (8)

**Proof:** See Appendix 1.7

The mixed strategy equilibrium solution for this inter-alliance competition, when the partners share profits proportionally, is given by a similar system of three equations (see Appendix 1.8).

**Effect of market size.** When firms in alliance \( i \) are developing products in parallel, the partner investing the most influences the utility of the new product, \( U(i) \). How much should a partner in such an alliance invest in the alliance? Should a partner invest more so that its investment has a critical influence on the outcome of the inter-alliance competition? Or should he invest nothing as any investment less than the maximum has no bearing on the utility of the new product? Investing nothing is the equilibrium strategy for the within-alliance conflict. But as the attractiveness of the market at stake increases, partners developing products in parallel increase their investments in the joint endeavor as shown in Figs. 2A and 2B. These two figures display the mixed strategy equilibrium solutions for the equal and proportional profit-sharing rules, respectively. However, inspection of Figs. 3A and 3B reveals that partners developing a product in parallel commit fewer resources compared to those in same-function alliances irrespective of the profit-sharing arrangement. Such a behavior is a consequence of the way firm inputs combine to determine the utility of the new product. Any investment less than the maximum has no bearing on the utility of the new product, when partners develop the product in parallel. So, the inclination to completely free ride is stronger when products are developed in parallel.

---------- Insert Figs. 2 and 3 ----------

These results are summarized in the following proposition:
**Proposition 2**: As the size of the market at stake increases, the resources committed by partners to the alliance increase, irrespective of whether they share profits equally or proportionally and whether they develop the product in parallel or in same-function alliances. Partners in same-function alliances commit more resources than those developing products in parallel.

**Effect of profit-sharing arrangement.** In same-function alliances, we observed that the profit-sharing arrangement matters when the market is small, but not when it is large. When products are developed in parallel, as shown in Figs. 2A and 2B, the motivation to win the competition increases and accordingly competitive investments increase under either profit-sharing arrangement. However, the attractiveness of the market can never keep the inclination to free ride under check to the extent that there is no need to monitor the resource commitments of partners in the alliance. Hence, partners sharing profits equally commit fewer resources even when the market is large. This difference is evident in Figure 3C. Such an investment pattern is in variance with the behavior observed in same-function alliances.

Therefore, we have:

**Proposition 3.** Partners developing a new product in parallel and sharing profits equally, instead of proportionally, commit fewer resources even when the market is sufficiently large.

In sum, the effect of profit-sharing changes with the type of alliance: partners make comparable investments under either profit-sharing arrangement in a same-function alliance, if the market size at stake is large; they commit more resources under proportional profit-sharing arrangement, when products are developed in parallel. Additionally, partners in a same-function alliance invest more resources than those developing products in parallel.\(^4\)

---

\(^4\)Modeling cross-functional alliances in a similar way, we find that the partners in such alliances are involved in coordination games, which have multiple Nash equilibria in pure strategies. The details of the analysis of cross-functional alliances are omitted here (but see Amaldoss 1998).
4. Laboratory Test

In this section we describe a controlled laboratory test of some of the key implications of the game-theoretical analysis. Our goal is to examine to what extent the actual behavior of financially motivated agents conforms to the qualitative and quantitative predictions of the game-theoretical model, when these agents are placed in a situation that satisfies the assumptions of the model.

Of course, it is unlikely that decision makers would solve the resource commitment problem using the mathematics outlined above. In the absence of a clear knowledge of how to optimally allocate resource, subjects may make decisions using simplifying heuristics that have limited normative status. For example, one possibility is that we may observe subjects systematically over-investing out of altruistic respect for their partners. Such a regard for others has been observed in the play of the Prisoner's Dilemma game (e.g., Dawes 1980, Isaac and Walker 1988), the ultimatum game (e.g., Hoffman et al. 1993, Forsythe et al 1994), and the Centipede game (e.g., McKelvey and Palfrey 1992). On the other hand, it is also possible that agents may under-invest when they recognize the opportunities for free riding. The fear of becoming a sucker or the greed to exploit free-riding opportunities may motivate agents to reduce their investment (Rapoport 1987, Rapoport and Bornstein 1987). Further, in this game agents may even choose to invest nothing and take the guaranteed payoff that is equal to their endowment. Finally, the behavior of agents may not be as sensitive to changes in either the size of market or the profit-sharing arrangement as predicted by theory.

To address these issues, we examine how actual investment decisions are made in a simulated market of competing alliances. In this market we mimic the different types of alliances by appropriately modifying how the inputs of partners combine to determine the utility of a hypothetical new product. Further, we change the size of the market at stake and the profit-sharing arrangement to create different experimental conditions.
Specifically, the empirical work focuses on two central questions.

1) How does profit-sharing arrangement affect the resources committed by partners in a same-function alliance? Qualitatively, the model implies that when the market is large in relation to each partner’s endowment, the equilibrium investment patterns under both profit-sharing arrangements are similar. When the market size is small, the level of investment under the proportional profit-sharing arrangement is greater than that under the equal profit-sharing arrangement. Quantitative predictions about the probabilities of investing 0, c/2, and c capital are also testable.

2) When products are developed in parallel, is the investment pattern different from that observed in a same-function alliance? Qualitatively, the model predicts that partners developing a new product in parallel commit fewer resources for the joint endeavor in comparison to partners in a same-function alliance. Quantitative predictions about the actual probabilities of investing c, c/2, and 0 can also be tested.

The laboratory tests are presented in two parts. Study 1 examines the effect of the profit-sharing arrangement in same-function alliances. Study 2 contrasts the investment behavior when products are developed in parallel against the resource commitment observed in same-function alliances when profits are shared equally.

**Study 1: Effects of Profit-Sharing Arrangement in Same-Function Alliances**

**Subjects.** Seventy-two undergraduate and graduate students participated in the experiment. The subjects were recruited through advertisements and class announcements promising monetary reward contingent on performance. In addition to their earnings, the subjects were paid a show-up fee of $5. All the transactions in the experiment were conducted in a fictitious currency called "francs". At the end of the experiment, the cumulative individual payoffs were converted into US dollars. On the average, subjects earned $16-20.
**Procedure.** The subjects were divided into six sets of twelve players each. Each group participated in a single session that lasted about ninety minutes. The experiments were conducted in laboratories with computer facilities for studying multi-player, multi-period interactive decision making.

On arriving at the laboratory, the subjects were randomly seated in twelve separate computer booths. Before the commencement of the experiment, the subjects were asked to read the instructions (Appendix 2), which included a detailed example. After reading the instructions, the subjects participated in five practice trials designed to familiarize them with the task. Questions about the experimental procedure were answered during the practice trials. Further communication between the subjects was strictly prohibited.

On each trial, the twelve subjects were randomly matched into six pairs. Each of these pairs was set to compete with another pair according to a predetermined assignment schedule. The assignment schedule ensured that each subject was paired with a different subject in each round and competed with a different group on each trial. Consequently, the subjects had no way of knowing the identity of their partner or competitors on any given trial.

At the commencement of the experiment the subjects were informed of the profit-sharing arrangement. Partners in an alliance shared the profits either equally or in proportion to their investments. At the beginning of each trial, each subject was provided a capital of 2 francs in all the experimental conditions ($c = 2$ francs). The prize for winning the competition, $m$, was varied over the experimental conditions. The prize was set at $m = 6$, 12, or 20 francs ($c/m = 0.33$, $0.17$, or $0.1$). The profit-sharing rule, endowment, and prize value remained fixed throughout the experiment.

Based on the profit-sharing arrangement and the prize at stake, each partner decided how much to contribute for the joint endeavor: 0, 1, or 2 francs. Once all the subjects made their decisions, the computer calculated the total investment made by each alliance. The alliance that
invested more won the competition. Ties were counted as losses (i.e., \( s = 0 \)). Further, we set \( g = 0 \), as it helps focusing on the effect of profit-sharing arrangement and market size.

At the end of each trial, subjects were informed of the total investments made by the winning and losing alliance, the alliance winning the competition, and the subject’s payoff for the trial.⁵

The subjects were provided with paper and pencil to help them recording the outcomes of previous trials, if they wished to do so. The stage game was played repeatedly for 160 trials except in one treatment. Subjects in the medium reward condition under equal profit-sharing arrangement played the game for only 90 trials. At the end of the experiment, the subjects were paid in U.S. dollars according to their cumulative earnings, debriefed, and dismissed.

**Experimental Design.** The study involved a \( 2 \times 3 \) between-subjects factorial design with two profit-sharing rules (equal and proportional) crossed with three levels of endowment to market size ratio \( (c/m = 0.33, 0.17, \text{ and } 0.10) \).

**Results.** First, we compare the distribution of strategies played by subjects against the equilibrium solution. Then, we test the empirical distribution of strategies for the differential effect of profit-sharing arrangement.

**Equal Profit-Sharing Arrangement.** Table 2 (column 3) reports the relative frequency of the three strategies played by subjects under the equal profit-sharing rule. These relative frequencies were computed across subjects and trials. The corresponding equilibrium predictions are presented in column 4. The investment pattern of the subjects in the high reward

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⁵For example, suppose the capital endowed to each subject at the beginning of a trial is 2 francs, and the prize for winning the competition is 6 francs. Let the partners share profits equally. Also suppose that player \( k \) of alliance \( i \) invests 2 francs and his partner invests 1 franc in the new product development research. Let the competing alliance \( j \) make a total investment of 2 francs in the development of their new product. Alliance \( i \) has invested more for developing the new product, so alliance \( i \) group wins the competition. Each member of the winning alliance gets an equal share of the prize, that is 3 francs each. So, the payoff for player \( k \) in the winning alliance is 3 francs and the payoff for his partner is 4 francs.

\[
\begin{align*}
\text{Player } k\text{'s payoff} & = \text{endowment} - \text{investment} + 50\% \text{ of reward} = 2 - 2 + 3 = 3 \text{ francs.} \\
\text{Payoff for player } k\text{'s partner} & = \text{endowment} - \text{investment} + 50\% \text{ of reward} = 2 - 1 + 3 = 4 \text{ francs.}
\end{align*}
\]

Similarly, we provided an example to illustrate proportional profit-sharing arrangement (see Appendix 2 for instructions to subjects).
condition \((c/m = 0.1)\) is very consistent with theory. Whereas the subjects should invest \(c\), \(c/2\), and \(0\) francs 88, 6, and 6 percent of the time, respectively, in actuality they contributed 2 \((c)\), 1 \((c/2)\), and 0 francs 81, 11, and 9 percent of the time. The Kolmogorov-Smirnov test of goodness of fit does not reject the null hypothesis that the predicted and actual distributions of strategies are equal \((D_{160} = 0.067, p > 0.20)\). Similarly, the Kolmogorov-Smirnov test does not reject the same null hypothesis in the medium reward condition \((D_{160} = 0.071, p > 0.20)\).

--------- Insert Table 2 -------

Table 2 indicates a discrepancy between actual and predicted aggregate behavior in the low reward condition. In equilibrium, the probability of investing \(c\), \(c/2\), and \(0\) francs should be 6, 44, and 50 percent of the time, respectively. In contrast, the subjects played these strategies 19, 30, and 51 percent of the time, respectively. The Kolmogorov-Smirnov test of goodness of fit rejects the null hypothesis \((D_{160} = 0.128, p < 0.01)\). In the low reward condition, subjects invested \(0\) francs in approximately half of all the trials as predicted. However, these players invested \(c\) (or \(2\) francs) three times more often than predicted, and \(c/2\) (or \(1\) franc) about 14 percent less than predicted. Such a tendency to over-contribute has been observed repeatedly in experiments designed to test for provision of public goods (Cooper et al. 1996, see Dawes and Thaler 1988 for an overview).

The overall mean proportions presented in Table 2 do not reveal whether the relative frequency of the strategies steadily changed with experience. This fact can be better appreciated by inspecting of Figs. 4A, 4B, and 4C. These three figures display the trends in the choice of strategies played by subjects in the high, medium, and low reward conditions across the 160 trials (in blocks of 10 trials). The investment pattern in the high reward condition (Fig. 4A) seems to be very stable over time. There is a small tendency in the medium reward condition (Fig. 4B) for the relative frequency of investing the entire resource \((c)\) to decrease over trials. A
considerably stronger trend is observed in the low reward condition (Fig. 4C) with the relative frequency of investing $c$ francs steadily declining over trials and approaching equilibrium play. Interestingly, in the low reward condition the observed relative frequencies of the three strategies in the last block of ten trials do not differ significantly from the equilibrium predictions ($D_{160} = 0.086, p > 0.1$).

---------- Insert Figure 4 ----------

Proportional Profit Sharing. Table 2 reports the actual (column 5) and predicted (column 6) distributions of the three strategies in same-function alliances, where profits were shared proportionally. The mean proportions are based on the behavior of 12 subjects over 160 trials.

In the aggregate, subjects in the high reward condition ($c/m = 0.1$) conformed remarkably well to the equilibrium solution. In equilibrium, subjects should invest $c$, $c/2$, and $0$ francs 88.5, 2.8, and 8.7 percent of the time, respectively. The subjects actually invested 2, 1, and 0 francs on 84.4, 3.2, and 12.3 percent of the occasions. The Kolmogorov-Smirnov test does not reject the null hypothesis that the observed and predicted distributions are equal ($D_{160} = 0.041, p > 0.20$). Similar result holds for the medium reward condition. The Kolmogorov-Smirnov test result is $D_{160} = 0.041 (p > 0.20)$, suggesting no difference between observed relative frequencies and the equilibrium prediction of choices.

As in the equal profit-sharing rule, we find discrepancies between the actual behavior of the subjects in the low reward condition and the corresponding equilibrium prediction. In equilibrium, subjects should invest $c$, $c/2$, and $0$ francs 44.2, 19.7 and 36.1 percent of the time, respectively. In contrast, subjects played these strategies 60.6, 8.5, and 30.9 percent of the time, respectively. This difference between predicted and actual behavior is statistically significant (Kolmogorov-Smirnov $D_{160} = 0.164, p < 0.01$).

These overall mean proportions again do not reveal the existence of learning trends, if any, across the 160 trials. Figures 5A, 5B, and 5C display the trends in the choice of strategies
across the 160 trials (in blocks of ten trials each) for the high, medium, and low reward conditions, respectively. Figure 5A shows that after the first two blocks of ten trials each, the results for the high reward condition are very stable. In the medium reward condition (Fig. 5B) the probability of investing \( c \) francs decreases while the probability of investing \( 0 \) francs increases over time in the direction of equilibrium play. In the low reward condition (Fig. 5C), we again observe that the relative frequency of investing \( c \) francs declines across trials in the direction of the equilibrium solution.

-------- Insert Figure 5 --------

Comparison of the two profit sharing arrangement. Finally, we compare the observed behavior of subjects under the two profit-sharing arrangements\(^6\). Consider the two empirical distributions in columns 3 and 5 of Table 2. As predicted by the model, the observed behavior under both the equal and proportional profit-sharing arrangement rules is similar in the high reward condition. The two-sample Kolmogorov-Smirnov test result shows no significant difference between the two empirical distributions. \( D_{160,160} = 0.044, p > 0.20 \). Also consistent with the model, the type of profit-sharing arrangement in the low reward condition does matter. Subjects sharing the profit proportionally invested \( c, c/2, \) and \( 0 \) francs 60.6, 8.5, and 30.9 percent of the time, whereas the corresponding percentages for subjects sharing the profit equally were 19, 30, and 51. The Kolmogorov-Smirnov test rejects the null hypothesis that these two empirical distributions are equal \( D_{160,160} = 0.416, p < 0.01 \). In the medium reward condition, we find that both profit-sharing arrangements evoked a similar pattern of investment \( (D_{160,160} = 0.075, p > 0.20) \).

Study 2: Effect of Type of Alliance on the Resources Committed by the Partners

\(^6\) The results of an analysis of variance with 2 between-subjects factors (profit-sharing arrangement and reward condition) are consistent with the predictions of the model. The main effect of reward is significant \( (p < 0.001) \). The model implies that profit-sharing arrangement interacts with market size: when market size is large profit-sharing arrangement doesn’t matter, but when market is small profit-sharing matters. In keeping with the theory, the interaction effect of reward and profit-sharing arrangement is significant \( (p < 0.001) \). The investments made
In this study we investigated a set of three new experimental conditions on parallel development of new products. Partners in these alliances shared their profit equally. In Study 1 we included three conditions on the investment behavior of partners in same-function alliances where profits were shared equally. We pooled data from these six conditions to examine the question whether the type of alliance affect the resources committed by a partner to the collaboration.

**Subjects.** Another set of thirty-six students was recruited from the same population of subjects for studying parallel development of products. Twelve subjects participated in each of the three experimental conditions. The subjects were paid a show-up fee of $5 in addition to the money they earned in the experiment. On the average, the subjects earned $16-20 and spent about 90 minutes in this experiment.

**Procedure.** The experimental procedure closely follows the one outlined in Study 1. A key difference in this experiment was how the winning alliance was determined. Each subject was endowed with 2 francs at the beginning of each trial in all the experimental conditions ($c = 2$ francs). But the size of prize, $m$, differed between conditions. Specifically, we set $m$ at 6, 12, or 20 francs so that $c/m = 0.33, 0.17$, or $0.1$ as in Study 1. Neither the endowment nor reward changed during the entire duration of the experiment. Once all the subjects made their investment decisions, the computer calculated the maximum investment made by an individual in each of the two competing alliances. The alliance whose maximum investment was higher was declared the winner. Ties were counted as losses ($s = 0$). At the end of each trial, subjects were informed of the maximum investment made by the winning and losing alliances, the alliance winning the competition, and the individual payoff for the trial. The subjects participated in five practice rounds, and then advanced to play the 160 trials.

by subjects sharing profits proportionally in the low reward condition were high enough to produce a main effect for profit-sharing ($p < 0.003$).
**Experimental Design.** Study 2 involved a $3 \times 2$ between-subjects factorial design with three levels of endowment to market size ratio ($c/m = 0.33, 0.17, 0.11$) and two types of alliances.

**Results.** First we address how well our model predicts the behavior of partners developing products in parallel. Then we test for the differential effect of type of alliance on the behavior of partners.

**Parallel Development of New Products.** Table 3 (column 3) reports the actual distribution of strategies computed across subjects and trials when profits were shared equally. Whereas subjects in the high reward condition ($c/m = 0.1$) were expected to invest $c$, $c/2$, and 0 capital 38.5, 15.1 and 46.4 percent of the time, respectively, in actuality they contributed 2, 1, and 0 francs 40.8, 18.0, and 41.2 of the time. The Kolmogorov-Smirnov test does not reject the null hypothesis that the theoretical and empirical distributions are equal ($D_{160} = 0.052, p > 0.20$). The same result holds for the medium reward ($D_{160} = 0.044, p > 0.20$) and the low reward ($D_{160} = 0.093, p > 0.10$) conditions. The support for the mixed strategy equilibrium solution in these three conditions is remarkably strong.

------Insert Table 3 about here------

Figure 6 (parts A, B, and C) displays the trends in the distribution of strategies across blocks of ten trials. In the high reward condition (Fig. 6A), the distribution of strategies stabilizes after two to three blocks. In contrast, the probability of investing 2 francs increases and the probability of investing 0 francs decreases over time in the medium reward condition (Fig. 6B). In the low reward condition (Fig. 6C), we find a very slow increase in the probability of investing all the resources and a corresponding slow decline in the other two probabilities.

------ Insert Figure 6 ------

**Comparison of same-function alliance and parallel development of products.** Having examined the empirical distribution of strategies for parallel development of new products, we
proceed to answer the question: Does the type of alliance affect the level of resources committed by a partner to the collaboration? Comparison of the two distributions (column 3 of Table 2 for same-function alliance and column 3 of Table 3 for parallel development of products) indicates that the behavior of subjects is in keeping with model7. The investments are considerably lower when products are developed in parallel. In the high reward condition, partners in same-function alliance invested more as predicted by theory. Subjects in same-function alliance contributed 2, 1, and 0 francs 81, 11 and 9 percent of the time, respectively. In contrast, subjects developing the product in parallel invested 2, 1, and 0 francs 40.8, 18.0, and 41.2 percent of the time, even though the reward condition was same. The two-sample Kolmogorov-Smirnov test indicates that these two empirical distribution of strategies are not the same ($D_{160,160} = 0.402, p < 0.01$). As predicted by the model, partners in same-function alliances invested more in the medium and low reward conditions as well. The Kolmogorov-Smirnov tests attest that the distribution of strategies differed with the type of alliance both in the medium ($D_{160,90} = 0.35, p < 0.01$) and low ($D_{160,160} = 0.14, p < 0.05$) reward conditions8.

5. A Preliminary Field Test

Robertson and Gatignon (1998) surveyed technology alliances in 1994 as part of the Wharton Study on Innovation Development. In this study, they obtained perceptual data on the behavior of partners in R&D alliances. We used their field data set to test whether the reported

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7 The results of an analysis of variance based on 6,480 data points obtained by pooling the first 90 observations provided by each of 12 subjects in the 6 treatments (2 types of alliances x 3 reward conditions) are consonant with the model. The main-effect for type of alliance is significant ($p < 0.0001$). Besides the main effect for reward condition ($p < 0.001$) is also significant.

8 Another implication of the model is that subjects mix strategies. If subjects perfectly mixed strategies as suggested by theory then each investment decision was randomly drawn from an underlying probability distribution. This implies that the joint probability of observing an investment of $c$ francs in periods $t-1$ and $t$ is equal to the square of the marginal probability of investing $c$ francs, that is $p_j^2$. It is possible that subjects mixed strategies but not as perfectly as implied by the theory. Then the level of sequential dependencies in strategies could be either more (repetition bias) or less (over-alternation bias) than that implied by a random draw from an underlying distribution. We find that subjects mixed strategies, but not as perfectly as implied by a random draw process. The level of repetition bias is less than that reported in Rapoport and Amaldoss (1996) and Rapoport and Budescu (1992). This inertia is consistent with our finding that subjects learned ($p < 0.01$) over the trials to conform to theory in all these experiments.
behavior of corporate partners in same-function alliances is directionally consistent with our model and the experimental evidence.

Data. The Robertson and Gatignon survey covered 53 technology alliances that developed a substantial technology. Minor innovations such as line extensions of existing products were excluded from the purview of the study. Seventy nine percent of these alliances involved only two partners. The respondents were R&D directors of firms participating in these technology alliances. Only a single key informant was surveyed in each of these alliances (Kumar, Stern, and Anderson 1993). The questionnaire included several statements about the partners in these alliances and the business context. The R&D directors indicated the level to which they agreed or disagreed with each of these statements using 6-point Likert scales. The details of this survey are discussed in Robertson and Gatignon (1998).

Operationalization of Theoretical Constructs. Our theoretical model focuses on the resources committed by partners to the collaboration. We are interested in testing how this resource commitment is influenced by the attractiveness of the market and profit-sharing arrangement. Thus, the relevant theoretical constructs are resource committed by a partner (Resource Commitment), sharing of the profit (Share), and market attractiveness (Market).

Resources Committed by Partner (RESOURCE COMMITMENT). Robertson and Gatignon followed a single key informant procedure for collecting the survey data. Self-reports on resource commitments have the potential to be biased. Therefore, we focused on the respondent’s evaluation of the resources committed by his partner in the collaboration. We developed a 4-item scale to measure the resources committed by a partner. These four items assessed the size of the resources committed, specificity of the investments, and quality of R&D personnel allocated for the collaboration. The Cronbach’s Alpha for this construct is 0.817. A list of the items and item to total correlation are presented in Table 4. The resource
commitments of the partnering firms in these 53 alliances have a mean score of 15.88 and a standard deviation of 4.2 on this scale.

**Market Attractiveness (MARKET).** We developed a three-item scale for measuring the attractiveness of a market. These items are related to the growth of the market and consumer demand for the product category. The Cronbach’s Alpha is 0.877. The list of the items and the item to total correlation are presented in Table 4. The attractiveness of the markets served by the 53 alliances has a mean score of 11.84 and a standard deviation of 4.2 on this scale.

**Share of Benefit (SHARE).** The survey provides information on the relative benefit that accrued to each partner. There are instances where a firm benefited more than its partner. There are also instances where they shared the benefits equally. We developed a measure of relative share of benefit using two items. These items are listed in Table 4. The Cronbach’s Alpha is 0.58. We classified the partners into three groups using the share scale: partners benefiting more, equal, or less.

**Results.** We first examined the bi-variate correlation to understand how a partner’s resource commitment is related to share of benefit (SHARE) and market attractiveness (MARKET). For this analysis, we used the information on all the 53 alliances covered in the survey. Consistent with our model, we found a significant correlation between market attractiveness and partner’s resource commitment ($\rho = 0.414, p < 0.002$). The relationship between share of benefit and resource commitment is not significant ($p > 0.4$). Next, we tested simultaneously the effect of market attractiveness and share of benefit. We found that resource commitment was related to market attractiveness ($F_{(1,47)} = 2.87, p < 0.097$). The manner by which the benefit of collaboration is shared does not affect resource commitment ($F_{(2,47)} = 0.92, p > 0.40$). The interaction effect of market and share of benefit is marginally significant ($F_{(1,47)} = 2.33, p < 0.10$), implying that

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*The scales reported in this field study were constructed using the original survey data collected by Robertson and Gatignon in 1994 as part of Wharton Study on Innovation Development. Note that the items used to
resource commitment increases more rapidly as the market attractiveness increases when partners share the benefit equally. These results are directionally consistent with the theoretical model and complement our experimental results.

We recognize that the real world is more complicated than our stylized model. Further, the empirical constructs are based on the perceived, rather than actual, behavior of partners in these technology alliances. The sample sizes are also quite small. Yet, when viewed along with the experimental results, these results add strength to the proposed theoretical model.

6. Conclusions

We developed a game-theoretical model of competition among alliances and then examined the effect of profit-sharing arrangement and type of alliance on the conduct of the partners. The model provides insights about the effect of type of alliance and profit-sharing arrangement on the behavior of alliance partners. A key finding of our model is that when the reward for winning a new product competition is high, the competitive investment pattern under both proportional and equal profit-sharing arrangements are comparable for same-function alliances. However, this result does not hold when partners develop products in parallel.

The impact of type of alliance on the conduct of partners has not been previously addressed in strategic alliance literature. We find that partners in a same-function alliance commit more resources than those developing products in parallel. Among partners developing a product in parallel, those sharing profits equally commit fewer resources than those sharing profits proportionally.

The behavior of subjects in a controlled laboratory setting conforms to the qualitative and the quantitative predictions of the model. The behavior of corporate partners in the

develop the RESOURCE COMMITMENT and the SHARE scales were not used in Robertson and Gatignon (1998).
technology alliances surveyed by Robertson and Gatignon is also directionally consistent with our model of same-function alliances.

In the laboratory study, the actual resource commitments of subjects closely followed the point predictions of the model. Given the learning trends observed in the aggregate data, it would be interesting to investigate how well adaptive learning mechanisms can account for the behavior of individual subjects (Camerer and Ho in press, Erev and Roth in press, Erev and Rapoport 1998, Mookherjee and Sopher 1997, Roth and Erev 1995).

The model can be extended to examine the effect of alliance size and probabilistic choice process. Another extension concerns alliances that do not involve explicit profit-sharing arrangement. In the context of marketing, product bundling (e.g., Venkatesh and Mahajan 1993) and co-branding (e.g., Park et al. 1996) are instances of such collaboration. For instance, Microsoft and Intel are independent profit maximizing firms, whose success is linked to the popularity of the 'Wintel' standard. The popular acceptance of the Wintel standard depends on the marketing mix decisions of both Microsoft and Intel. Extensions of the model can be used to understand how the type of alliance and market characteristics affect the marketing mix decisions for bundled technology products.
References


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Table 1. Payoff Matrices for the Intra-Alliance Conflict and Inter-Alliance Competition

**Same-Function Intra-Alliance Conflict**

Player $i_j$’s Investment

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</tr>
<tr>
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<td>$3g/4 - c/2$, $3g/4 - c$</td>
<td>$g/2 - c/2$, $g/2 - c/2$</td>
<td>$g/4 - c/2$, $g/4$</td>
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<td>$0$</td>
<td>$g/2$, $g/2 - c$</td>
<td>$g/4$, $g/4 - c/2$</td>
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**The Inter-Alliance Competition**

$T_i$

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<th></th>
<th>0</th>
<th>$c/2$</th>
<th>$C$</th>
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<th>$2c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>s, s</td>
<td>0, m</td>
<td>0, m</td>
<td>0, m</td>
<td>0, m</td>
</tr>
<tr>
<td>$c/2$</td>
<td>m, 0</td>
<td>s, s</td>
<td>0, m</td>
<td>0, m</td>
<td>0, m</td>
</tr>
<tr>
<td>C</td>
<td>m, 0</td>
<td>m, 0</td>
<td>s, s</td>
<td>0, m</td>
<td>0, m</td>
</tr>
<tr>
<td>$3c/2$</td>
<td>m, 0</td>
<td>m, 0</td>
<td>m, 0</td>
<td>m, s</td>
<td>0, m</td>
</tr>
<tr>
<td>$2c$</td>
<td>m, 0</td>
<td>m, 0</td>
<td>m, 0</td>
<td>m, 0</td>
<td>s, s</td>
</tr>
</tbody>
</table>

**Intra-Alliance Conflict when Products are Developed in Parallel**

Player $i_j$’s Investment

<table>
<thead>
<tr>
<th></th>
<th>$c$</th>
<th>$c/2$</th>
<th>$0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c$</td>
<td>$g-c$, $g-c$</td>
<td>$g - c$, $g - c/2$</td>
<td>$g - c$, $g$</td>
</tr>
<tr>
<td>$c/2$</td>
<td>$g - c/2$, $g - c$</td>
<td>$g/2 - c/2$, $g/2 - c/2$</td>
<td>$g/2 - c/2$, $g/2$</td>
</tr>
<tr>
<td>$0$</td>
<td>$g$, $g - c$</td>
<td>$g/2$, $g/2 - c/2$</td>
<td>$0$, $0$</td>
</tr>
</tbody>
</table>

**Note:**
- $c$ is the investment capital available to each partner in the alliance,
- $g$ is the maximum value of the side benefit that each partner gets on developing the new technology,
- $m$ is the value of the market that the winning alliance captures, and
- $s$ is the value of the market each alliance gets in case there is a tie.
Table 2. Comparison of Observed and Mixed Strategy Equilibrium Choice of Investments

<table>
<thead>
<tr>
<th>Reward Condition</th>
<th>Investment</th>
<th>Profit-Sharing Arrangement</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Equal</td>
<td>Observed</td>
<td>Equilibrium</td>
<td>Observed</td>
<td>Equilibrium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Behavior</td>
<td>Prediction</td>
<td>Behavior</td>
<td>Prediction</td>
</tr>
<tr>
<td>High Reward</td>
<td>High ($c$)</td>
<td>0.81</td>
<td>0.88</td>
<td>0.844</td>
<td>0.885</td>
<td></td>
</tr>
<tr>
<td>($c/m = 0.1$)</td>
<td>Medium ($c/2$)</td>
<td>0.11</td>
<td>0.06</td>
<td>0.032</td>
<td>0.028</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low ($\theta$)</td>
<td>0.09</td>
<td>0.06</td>
<td>0.123</td>
<td>0.087</td>
<td></td>
</tr>
<tr>
<td>Medium Reward</td>
<td>High ($c$)</td>
<td>0.67</td>
<td>0.74</td>
<td>0.745</td>
<td>0.786</td>
<td></td>
</tr>
<tr>
<td>($c/m = 0.17$)</td>
<td>Medium ($c/2$)</td>
<td>0.14</td>
<td>0.12</td>
<td>0.074</td>
<td>0.052</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low ($\theta$)</td>
<td>0.19</td>
<td>0.14</td>
<td>0.181</td>
<td>0.161</td>
<td></td>
</tr>
<tr>
<td>Low Reward</td>
<td>High ($c$)</td>
<td>0.19</td>
<td>0.06</td>
<td>0.606</td>
<td>0.442</td>
<td></td>
</tr>
<tr>
<td>($c/m = 0.33$)</td>
<td>Medium ($c/2$)</td>
<td>0.30</td>
<td>0.44</td>
<td>0.085</td>
<td>0.197</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low ($\theta$)</td>
<td>0.51</td>
<td>0.50</td>
<td>0.309</td>
<td>0.361</td>
<td></td>
</tr>
</tbody>
</table>

Note: $c$ is the investment capital available to each partner in the alliance, and $m$ is the value of the market that the winning alliance captures. Keeping $\tilde{c} = 2$ francs, we varied $m$ to 20, 12 and 6 francs such that $c/m = 0.1, 0.17$ and 0.33 respectively. So the reward for winning the competition is high when $c/m = 0.1$, and low when $c/m = 0.33$. 

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Table 3. Comparison of Observed and Predicted Choice of Investment when Products are Developed in Parallel

<table>
<thead>
<tr>
<th>Reward Condition</th>
<th>Investment</th>
<th>Observed Behavior</th>
<th>Equilibrium Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>High reward ($c/m = 0.1$)</td>
<td>High ($c$)</td>
<td>0.408</td>
<td>0.385</td>
</tr>
<tr>
<td></td>
<td>Medium ($c/2$)</td>
<td>0.180</td>
<td>0.151</td>
</tr>
<tr>
<td></td>
<td>Low ($\theta$)</td>
<td>0.412</td>
<td>0.464</td>
</tr>
<tr>
<td>Medium reward ($c/m = 0.17$)</td>
<td>High ($c$)</td>
<td>0.315</td>
<td>0.271</td>
</tr>
<tr>
<td></td>
<td>Medium ($c/2$)</td>
<td>0.171</td>
<td>0.179</td>
</tr>
<tr>
<td></td>
<td>Low ($\theta$)</td>
<td>0.514</td>
<td>0.550</td>
</tr>
<tr>
<td>Low reward ($c/m = 0.33$)</td>
<td>High ($c$)</td>
<td>0.175</td>
<td>0.081</td>
</tr>
<tr>
<td></td>
<td>Medium ($c/2$)</td>
<td>0.170</td>
<td>0.225</td>
</tr>
<tr>
<td></td>
<td>Low ($\theta$)</td>
<td>0.655</td>
<td>0.693</td>
</tr>
</tbody>
</table>

Note: $c$ is the investment capital available to each partner in the alliance, and $m$ is the value of the market that the winning alliance captures. Keeping $c = 2$ francs, we varied $m$ to 20, 12 and 6 francs such that $c/m = 0.1, 0.17$ and 0.33 respectively. So the reward for winning the competition is high when $c/m = 0.1$, and low when $c/m = 0.33$. 


<table>
<thead>
<tr>
<th>Table 4: Study Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resources Committed by Partner (RESOURCE COMMITMENT)</strong></td>
</tr>
<tr>
<td>Cronbach’s Alpha = 0.8173</td>
</tr>
<tr>
<td>Correlation with total</td>
</tr>
<tr>
<td>Some of their best R&amp;D personnel to the alliance were allocated to the alliance</td>
</tr>
<tr>
<td>The alliance represented a fairly small commitment of their resources (statement reversed)</td>
</tr>
<tr>
<td>The alliance was a major percent of their R&amp;D investment</td>
</tr>
<tr>
<td>The alliance involved very specific investment in technological understanding</td>
</tr>
<tr>
<td><strong>Market Attractiveness (MARKET)</strong></td>
</tr>
<tr>
<td>Cronbach’s Alpha = 0.8700</td>
</tr>
<tr>
<td>Correlation with total</td>
</tr>
<tr>
<td>It is a high growth market</td>
</tr>
<tr>
<td>Customer demand is growing rapidly for the product category</td>
</tr>
<tr>
<td>Product category growth is negligible (reversed)</td>
</tr>
<tr>
<td><strong>Partner’s Share of Benefit (SHARE)</strong></td>
</tr>
<tr>
<td>Cronbach’s Alpha = 0.5821</td>
</tr>
<tr>
<td>Correlation with total</td>
</tr>
<tr>
<td>We benefited from the alliance more than our partner (reversed)</td>
</tr>
<tr>
<td>Our alliance partner benefited from the alliance more than we did</td>
</tr>
</tbody>
</table>
Appendix 1: Proofs of Theoretical Results

Section 1.1

Claim: Only mixed strategies exist for the inter-alliance competition game when \( s = 0 \) and \( m > 2c - g > 0 \).

Proof: If each firm in alliance \( i \) and alliance \( j \) invests 0, then the payoff of player \( k \) in alliance \( i \) is 0. If firm \( k \) deviates unilaterally and invests either \( c/2 \) or \( c \), the firm’s payoffs are \( g/4 - c/2 + m/2 \) or \( g/2 - c + m/2 \).

If investing 0 is an equilibrium, then

\[
0 - (g/4 - c/2 + m/2) \geq 0
\]

and

\[
0 - (g/2 - c + m/2) \geq 0.
\]

The first inequality implies that \( 2c - g \geq m \). But this violates our assumption that \( m > 2c - g \). Therefore investing 0 is not a symmetric equilibrium.

We next show that investing \( c/2 \) is not an equilibrium. Suppose that each firm in alliance \( i \) and alliance \( j \) invest \( c/2 \). Again the payoff for firm \( k \) is \( m/2 \). But if \( k \) unilaterally deviates and invests 0 or \( c \), then its payoff is \( g/4 \) or \( 3g/4 - c + m/2 \). For investing \( c/2 \) to be a symmetric equilibrium, the following two equations need to be satisfied:

\[
g/2 - c/2 \geq g/4
\]

and

\[
g/2 - c/2 \geq 3g/4 - c + m/2.
\]

The second inequality is violated if \( m > 2c - g \). Hence contributing \( c/2 \) is not a symmetric equilibrium.

Now suppose that each player invests \( c \). Then in equilibrium the following 2 inequalities must be satisfied for investing \( c \) to be a symmetric equilibrium:

\[
g - c \geq g/2
\]

and

\[
g - c \geq 3g/4 - c/2.
\]

Again the second inequality is violated if \( 2c - g > 0 \). Hence, contributing \( c \) is not a symmetric equilibrium.

Thus, the inter-alliance competition does not have a symmetric pure strategy equilibrium when \( s = 0 \) and \( m > 2c - g > 0 \).

Section 1.2

Claim: Only mixed strategies exist for the inter-alliance competition game when \( s = m/2 \) and

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\[ 4c > m > 2c - g > 0 \]

**Proof:** If each firm in alliance \( i \) and alliance \( j \) invests \( 0 \), then the payoff of player \( k \) in alliance \( i \) is \( m/4 \). If firm \( k \) deviates unilaterally and invests either \( c/2 \) or \( c \), the firm’s payoffs are \( g/4 - c/2 + m/2 \) or \( g/2 - c + m/2 \).

If investing \( 0 \) is an equilibrium, then
\[ m/4 \geq (g/4 - c/2 + m/2) \]

and
\[ m/4 \geq (g/2 - c + m/2). \]

The first inequality implies that \( 2c - g \geq m \). But this violates our assumption that \( m > 2c - g \). Therefore investing \( 0 \) is not a symmetric equilibrium.

We next show that investing \( c/2 \) is not an equilibrium. Suppose that each firm in alliance \( i \) and alliance \( j \) invest \( c/2 \). Again the payoff for firm \( k \) is \( g/2 - c/2 + m/4 \). But if partner \( k \) unilaterally deviates and invests \( 0 \) or \( c \), then its payoff is \( g/4 \) or \( 3g/4 - c + m/2 \). For investing \( c/2 \) to be a symmetric equilibrium, the following two equations need to be satisfied:
\[ g/2 - c/2 + m/4 \geq g/4 \]

and
\[ g/2 - c/2 + m/4 \geq 3g/4 - c + m/2 \]

The second inequality is violated if \( m > 2c - g \). Hence contributing \( c/2 \) is not a symmetric equilibrium.

Now suppose that each player invests \( c \). Then in equilibrium the following 2 inequalities must be satisfied for investing \( c \) to be a symmetric equilibrium:
\[ g - c + m/4 \geq g/2 \]

and
\[ g - c + m/4 \geq 3g/4 - c/2. \]

The first inequality is violated if \( m < 4c - 2g \). Hence, contributing \( c \) is not a symmetric equilibrium.

Thus, the inter-alliance competition does not have a symmetric pure strategy equilibrium when \( s = m/2 \) and \( 4c - 2g > c - g > 0 \).

**Section 1.3**

This section derives the system of equations that provide the equilibrium solution when partners in a same function alliance share profits equally.

Consider players \( i_1 \) and \( i_2 \) in alliance \( i \). Player \( i_1 \) could be involved with player \( i_2 \) in any of the 5 games presented below, depending on the total contribution of alliance \( j \), \( T_j \). (\( T_j = \{0, c/2, c, 3c/2, 2cf\} \)).
If $T_j = 0$:

<table>
<thead>
<tr>
<th>Player $i_j$'s Investment</th>
<th>$c$</th>
<th>$c/2$</th>
<th>$0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c$</td>
<td>$g + m/2 - c$ ,</td>
<td>$3g/4 + m/2 - c$ ,</td>
<td>$g/2 + m/2 - c$ ,</td>
</tr>
<tr>
<td>$g + m/2 - c$</td>
<td>$3g/4 + m/2 - c/2$</td>
<td>$g/2 + m/2 - c/2$</td>
<td>$g/2 + m/2$</td>
</tr>
<tr>
<td>$c/2$</td>
<td>$3g/4 + m/2 - c/2$ ,</td>
<td>$g/2 + m/2 - c/2$ ,</td>
<td>$g/4 + m/2 - c/2$ ,</td>
</tr>
<tr>
<td>$3g/4 + m/2 - c$</td>
<td>$g/2 + m/2 - c/2$</td>
<td>$g/4 + m/2$</td>
<td>$g/4 + m/2$</td>
</tr>
<tr>
<td>$0$</td>
<td>$g/2 + m/2$,</td>
<td>$g/4 + m/2$,</td>
<td>$s/2$,</td>
</tr>
<tr>
<td>$g/2 + m/2 - c$</td>
<td>$g/4 + m/2 - c/2$</td>
<td>$s/2$</td>
<td></td>
</tr>
</tbody>
</table>

If $T_j = c/2$:

<table>
<thead>
<tr>
<th>Player $i_j$'s Investment</th>
<th>$c$</th>
<th>$c/2$</th>
<th>$0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c$</td>
<td>$g + m/2 - c$ ,</td>
<td>$3g/4 + m/2 - c$ ,</td>
<td>$g/2 + m/2 - c$ ,</td>
</tr>
<tr>
<td>$g + m/2 - c$</td>
<td>$3g/4 + m/2 - c/2$</td>
<td>$g/2 + m/2 - c/2$</td>
<td>$g/2 + m/2$</td>
</tr>
<tr>
<td>$c/2$</td>
<td>$3g/4 + m/2 - c/2$ ,</td>
<td>$g/2 + m/2 - c/2$ ,</td>
<td>$g/4 + s/2 - c/2$ ,</td>
</tr>
<tr>
<td>$3g/4 + m/2 - c$</td>
<td>$g/2 + m/2 - c/2$</td>
<td>$g/4 + m/2$</td>
<td>$g/4 + m/2$</td>
</tr>
<tr>
<td>$0$</td>
<td>$g/2 + m/2$,</td>
<td>$g/4 + s/2$,</td>
<td>$0$,</td>
</tr>
<tr>
<td>$g/2 + m/2 - c$</td>
<td>$g/4 + s/2 - c/2$</td>
<td>$0$</td>
<td></td>
</tr>
</tbody>
</table>

If $T_j = c$:

<table>
<thead>
<tr>
<th>Player $i_j$'s Investment</th>
<th>$c$</th>
<th>$c/2$</th>
<th>$0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c$</td>
<td>$g + m/2 - c$ ,</td>
<td>$3g/4 + m/2 - c$ ,</td>
<td>$g/2 + s/2 - c$ ,</td>
</tr>
<tr>
<td>$g + m/2 - c$</td>
<td>$3g/4 + m/2 - c/2$</td>
<td>$g/2 + s/2 - c/2$</td>
<td>$g/2 + s/2$</td>
</tr>
<tr>
<td>$c/2$</td>
<td>$3g/4 + m/2 - c/2$ ,</td>
<td>$g/2 + s/2 - c/2$ ,</td>
<td>$g/4 - c/2$,</td>
</tr>
<tr>
<td>$3g/4 + m/2 - c$</td>
<td>$g/2 + s/2 - c/2$</td>
<td>$g/4$</td>
<td></td>
</tr>
<tr>
<td>$0$</td>
<td>$g/2 + s/2$,</td>
<td>$g/4$,</td>
<td>$0$,</td>
</tr>
<tr>
<td>$g/2 + s/2 - c$</td>
<td>$g/4 - c/2$</td>
<td>$0$</td>
<td></td>
</tr>
</tbody>
</table>
If $T_j = 3c/2$:

<table>
<thead>
<tr>
<th>Player $i_j$'s Investment</th>
<th>$c$</th>
<th>$c/2$</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c$</td>
<td>$g + m/2 - c$,</td>
<td>$3g/4 + s/2 - c$,</td>
<td>$g/2 - c$,</td>
</tr>
<tr>
<td>$g + m/2 - c$</td>
<td>$3g/4 + s/2 - c/2$</td>
<td>$g/2$</td>
<td></td>
</tr>
<tr>
<td>$c/2$</td>
<td>$3g/4 + m/2 - c/2$,</td>
<td>$g/2 - c/2$,</td>
<td>$g/4 - c/2$,</td>
</tr>
<tr>
<td>$3g/4 + m/2 - c$</td>
<td>$g/2 - c/2$</td>
<td>$g/4$</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>$g/2$,</td>
<td>$g/4$,</td>
<td>0</td>
</tr>
<tr>
<td>$g/2 - c$</td>
<td>$g/4 - c/2$</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

If $T_j = 2c$:

<table>
<thead>
<tr>
<th>Player $i_j$'s Investment</th>
<th>$c$</th>
<th>$c/2$</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c$</td>
<td>$g + s/2 - c$,</td>
<td>$3g/4 - c$,</td>
<td>$g/2 - c$,</td>
</tr>
<tr>
<td>$g + s/2 - c$</td>
<td>$3g/4 - c/2$</td>
<td>$g/2$</td>
<td></td>
</tr>
<tr>
<td>$c/2$</td>
<td>$3g/4 - c/2$,</td>
<td>$g/2 - c/2$,</td>
<td>$g/4 - c/2$,</td>
</tr>
<tr>
<td>$3g/4 - c$</td>
<td>$g/2 - c/2$</td>
<td>$g/4$</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>$g/2$,</td>
<td>$g/4$,</td>
<td>0</td>
</tr>
<tr>
<td>$g/2 - c$</td>
<td>$g/4 - c/2$</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

To construct the expected value of investing 0, $c/2$, or $c$ by firm $i_j$ in the collaboration, we need to understand partner $i_j$'s investment behavior ($I_{i_j} = \{0, c/2, c\}$) along with the behavior of the competing alliance, $T_j$ ($T_j = \{0, c/2, c, 3c/2, 2c\}$). In a symmetric equilibrium, the distribution of strategies is identical for all the players. Denote the probability of a player investing 0, $c$, and $c/2$ units of capital by $p_1$, $p_2$, and $p_3$ respectively. The joint probability of all players except player $i_j$ is provided in the table below.
Table 4: Same-Function Alliance

The Joint Probabilities (All players except player $i_j$ of alliance $i$)

\[
\begin{array}{|c|c|c|c|c|}
\hline
\text{Player } i_2 & 0 & c/2 & C & 3c/2 & 2c \\
\hline
\text{C} & p_3 p_1^2 & 2 p_1 p_2 p_3 & p_3 (2 p_1 p_3 + 2 p_2^2) & 2 p_3^2 p_2 & p_3^3 \\
\hline
\text{c/2} & p_2 p_1^2 & 2 p_1 p_2^2 & p_2 (2 p_1 p_3 + 2 p_2^2) & 2 p_2^2 p_3 & p_2 p_3^2 \\
\hline
0 & p_1^3 & 2 p_1^2 p_2 & p_1 (2 p_1 p_3 + 2 p_2^2) & 2 p_1 p_2 p_3 & p_1 p_3^2 \\
\hline
\text{Marginal} & p_1^2 & 2 p_1 p_2 & (2 p_1 p_3 + 2 p_2^2) & 2 p_2 p_3 & p_3^2 \\
\hline
\end{array}
\]

Now we can derive the system of 3 equations that will provide the equilibrium solution.

\[(s/2) \left(2 p_1^2 p_2 + p_2^3 + 2 p_1 p_2 p_3 + 2 p_2 p_3^2 - p_1^3 - 2 p_1 p_2^2 \right)
\]
\[-2 p_1 p_2 p_3 + (g/2) (p_1 - p_2) + (g/4) (p_1 - p_2) + (3g/4) p_3
\]
\[+ (m/2) (p_1^3 + 2 p_1 p_2^2 + p_2^2 p_3 - 2 p_1 p_3^2) = c/2 \quad (3)\]

\[(s/2) \left(p_1 p_2^2 + 2 p_1^2 p_3 + p_3^3 - 2 p_1^2 p_2 - p_2^3 - 2 p_2 p_3^2 + 2 p_2^2 p_3 \right)
\]
\[-2 p_1 p_2 p_3 + (g/2) (p_1 - p_2) - (g/4) p_1 + (3g/4) (p_2 - p_3) + g (p_3)
\]
\[+ (m/2) \left(2 p_1 p_2 + p_2^3 + 2 p_2 p_3^2 - 2 p_1 p_2^2 \right) = c/2 \quad (4)\]

\[p_1 + p_2 + p_3 = 1 \quad (5)\]

The parameters $m$, $s$ and $g$ are fixed and known. These parameters also satisfy the constraints $g > c$, $m/2 > c$, and $0 \leq s \leq m/2$.

Section 1.4:

This section outlines the system of equations that provides the equilibrium solution for the proportional profit-sharing arrangement. Our purpose is to compare the investment behavior under equal and proportional profit-sharing arrangement. We simplify the system of equations by setting $g = 0$. Denote the expected value of contributing $0$, $c/2$ and $c$ by $EV(0)$, $EV(c/2)$ and $EV(c)$, respectively. Using Table 4 in this Appendix, we can compute the expected values of investing $0$, $c/2$, and $c$. 

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\[ EV(0) = \frac{s}{2} (p_1^3) + c \]
\[ EV(c/2) = m (p_1^3) + m/2 (p_2 p_1^2) + m/3 (p_3 p_1^2) + s (2 p_1^2 p_2) + m/2 (2 p_1 p_2^2) + m/3 (2 p_1 p_2 p_3) + s/2 (p_2^2) (2 p_1 p_3 + p_2^2) + m/3 (p_3) (2 p_1 p_3 + p_2^2) + s/3 (2 p_3^2 p_2) + c/2 \]
\[ EV(c) = m (p_1^3) + 2 m/3 (p_2 p_1^2) + m/2 (p_3 p_1^2) + m (p_1^2 p_2) + 2 m/3 (2 p_1 p_2^2) + m/2 (2 p_1 p_2 p_3) + s (2 p_1 p_3 + p_2^2) + 2 m/3 (p_2) (2 p_1 p_3 + p_2^2) + m/2 p_3 (2 p_1 p_3 + p_2^2) + 2 s/3 (2 p_2^2 p_3) + m/2 (p_3^2 p_2) + s/2 (p_3^3) \]

Now the system of three equations that provides the equilibrium solution is:
\[ EV(c/2) - EV(0) = 0 \]
\[ EV(c) - EV(c/2) = 0 \]
\[ p_1 + p_2 + p_3 = 1 \]

Section 1.5

**Claim:** When partners develop new products in parallel and agree to share profits equally, the inter-alliance game has only a mixed strategy solution if \( m > 2c - g, s = 0 \) and \( c > 0 \).

**Proof:** If each firm in alliance \( i \) and alliance \( j \) invests \( 0 \), then the payoff of player \( k \) in alliance \( i \) is \( 0 \). If firm \( k \) deviates unilaterally and invests either \( c/2 \) or \( c \), the firm's payoffs are \( g/2 - c/2 + m/2 \) or \( g - c + m/2 \).

If investing \( 0 \) is an equilibrium, then
\[ 0 \geq g/2 - c/2 + m/2 \]
and
\[ 0 \geq g - c + m/2. \]

These inequalities imply that \( 2c - g \geq m \). But this violates our assumption that \( m > 2c - g \). Therefore, investing \( 0 \) is not a symmetric equilibrium.

We next show that investing \( c/2 \) is not an equilibrium. Suppose that each firm in alliance \( i \) and alliance \( j \) invest \( c/2 \). Then the payoff for firm \( k \) is \( g/2 - c/2 \). But if \( k \) unilaterally deviates and invests \( 0 \) or \( c \), then its payoff is \( g/2 \) or \( g - c + m/2 \). For investing \( c/2 \) to be a symmetric equilibrium, the following two equations need to be satisfied:
\[ g/2 - c/2 \geq g/2 \]
and
\[ g/2 - c/2 \geq g - c + m/2. \]

The second inequality is violated if \( m > 2c - g \). Hence contributing \( c/2 \) is not a symmetric equilibrium.
Now suppose that each player invests \( c \). Then in equilibrium the following 2 inequalities must be satisfied for investing \( c \) to be a symmetric equilibrium:

\[
g - c \geq g
\]

and

\[
g - c \geq g/2 - c/2.
\]

First inequality is violated if \( c > 0 \). Hence, contributing \( c \) is not a symmetric equilibrium.

Thus, this inter-alliance competition does not a symmetric pure strategy equilibrium when \( s = 0 \) and \( m > 2c - g \) and \( c > 0 \).

**Section 1.6**

**Claim:** When partners develop new products in parallel and share profits equally, the inter-alliance game has only a mixed strategy solution if \( s = m/2, 4c > m > 2c - g \).

**Proof:** If each firm in alliance \( i \) and alliance \( j \) invests \( 0 \), then the payoff of player \( k \) in alliance \( i \) is \( m/4 \). If firm \( k \) deviates unilaterally and invests either \( c/2 \) or \( c \), the firm's payoffs are \( g/2 - c/2 + m/2 \) or \( g - c + m/2 \).

If investing \( 0 \) is an equilibrium, then

\[
m/4 \geq g/2 - c/2 + m/2
\]

and

\[
m/4 \geq g - c + m/2.
\]

The first inequality implies that \( 2c - g \geq m \). But this violates our assumption that \( m > 2c - g \). Therefore, investing \( 0 \) is not a symmetric equilibrium.

We next show that investing \( c/2 \) is not an equilibrium. Suppose that each firm in alliance \( i \) and alliance \( j \) invest \( c/2 \). Then the payoff for firm \( k \) is \( g/2 - c/2 + m/4 \). But if \( k \) unilaterally deviates and invests \( 0 \) or \( c \), then its payoff is \( g/2 \) or \( g - c + m/2 \). For investing \( c/2 \) to be a symmetric equilibrium, the following two equations need to be satisfied:

\[
g/2 - c/2 + m/4 \geq g/2
\]

and

\[
g/2 - c/2 + m/4 \geq g - c + m/2.
\]

The second inequality is violated if \( m > 2c - g \). Hence, contributing \( c/2 \) is not a symmetric equilibrium.

Now suppose that each player invests \( c \). Then, in equilibrium, the following 2 inequalities must be satisfied for investing \( c \) to be a symmetric equilibrium:

\[
g - c + m/4 \geq g
\]

and

\[
g - c + m/4 \geq g - c/2.
\]
Again these inequalities will be violated if \( 4 \, c > m \). Hence, contributing \( c \) is not a symmetric equilibrium.

Thus, this inter-alliance competition does have not a symmetric pure strategy equilibrium when \( s = m/2 \), and \( 4 \, c > m > 2 \, c \cdot g \).

**Section 1.7**

In this section we derive the system of equations used to solve for the equilibrium solution when partners develop products in parallel and share profits equally.

The joint behavior of the competing alliance, \( j \), and partner \( i_2 \) is given in the table below. Using this information, as we did earlier, we compute the expected value of investing \( 0, c/2 \), or \( c \) by partner \( i_1 \) in alliance \( i \).

Table 5: Parallel Development of New Products

<table>
<thead>
<tr>
<th>Joint Probabilities (All players except partner ( i_j ) in alliance ( i ))</th>
<th>Max ( I_j, I_j )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 0 )</td>
<td>( c/2 )</td>
</tr>
<tr>
<td>( c )</td>
<td>( p_3 \cdot (p_1^3) )</td>
</tr>
<tr>
<td>( c/2 )</td>
<td>( p_2 \cdot (p_1^3) )</td>
</tr>
<tr>
<td>( 0 )</td>
<td>( p_1 \cdot (p_1^3) )</td>
</tr>
<tr>
<td>Marginal</td>
<td>( p_1 \cdot (p_1^2) )</td>
</tr>
</tbody>
</table>

Now using these probabilities we arrived at the system of three equations for studying the equilibrium behavior of a partner in alliance \( i \).

\[
\begin{align*}
(g/2 + m/2) \cdot p_1^3 - (g/2) \cdot (p_1 + 2 \cdot p_2^2) \cdot (2 \, p_1 \, p_3 + 2 \, p_2 \, p_3 + p_3^2) \\
+ p_1 \cdot (g/2 + s/2) \cdot (2 \, p_1 \, p_2 + p_2^2) \cdot (s/2) \cdot p_1^3 &= c/2 \\
\end{align*}
\]

\[
\begin{align*}
(g + m/2) \cdot (p_1^3 + p_1^2 \cdot p_3 + 2 \, p_1 \, p_2 + p_2^2 - 2 \, p_1 \, p_2 \, p_3 + p_3^2) \\
- (g/2 + m/2) \cdot (p_1^3 + p_1^2 \cdot p_2^2) - (g/2) \cdot (p_1 + p_2) \cdot (2 \, p_1 \, p_3 + 2 \, p_2 \, p_3 + p_3^2) \\
- (g/2 + s/2) \cdot (2 \, p_1^2 \cdot p_2^2 + p_1 \, p_2^2 + 2 \, p_1 \, p_2 + p_2^2) \\
+ (g + s/2) \cdot p_3 \cdot (2 \, p_1 \, p_3 + 2 \, p_2 \, p_3 + p_3^2) &= c/2 \\
\end{align*}
\]

\[
\begin{align*}
p_1 + p_2 + p_3 &= 1 \\
\end{align*}
\]

**Section 1.8**
In this section we present the system of equations for studying the equilibrium behavior when products are developed in parallel and profits are shared in proportion. Denote the expected value of contributing 0, c/2, and c by $EV(0)$, $EV(c/2)$, and $EV(c)$, respectively.

Using Table 5, we compute the expected values of investing 0, c/2, and c.

$$EV(0) = \frac{s}{2} (p_1^3) + \frac{g}{2} (p_2 p_1^2) + g (p_3 p_1^2) + \frac{g}{2} (p_2 (2 p_1 p_2 + p_2^2)) + (\frac{g}{2}) (p_3 (2 p_1 p_2 + p_2^2)) + g (2 p_1 p_3 + 2 p_2 p_3 + p_3^2) + c$$

$$EV(c/2) = \frac{(m + g/2)}{2} (p_1^3) + \frac{(m/2 + g/2)}{2} (p_2 p_1^2) + \frac{(m/3 + g)}{2} (p_3 p_1^2) + \frac{(s + g/2)}{2} (p_1 (2 p_1 p_2 + p_2^2)) + (\frac{(s/2 + g/2)}{2}) (p_2 (2 p_1 p_2 + p_2^2)) + (\frac{(m/3 + g)}{2}) (p_3 (2 p_1 p_2 + p_2^2)) + (\frac{(g/2)}{2}) (p_1 (2 p_1 p_3 + 2 p_2 p_3 + p_3^2)) + (\frac{(g/2)}{2}) (p_2 (2 p_1 p_3 + 2 p_2 p_3 + p_3^2)) + (\frac{(s/3 + g)}{2}) (p_3 (2 p_1 p_3 + 2 p_2 p_3 + p_3^2)) + c/2$$

$$EV(c) = \frac{(m + g/2)}{2} (p_1^3) + \frac{(2 m/3 + g)}{2} (p_2 p_1^2) + \frac{(m/2 + g)}{2} (p_3 p_1^2) + \frac{(m + g)}{2} (p_1 (2 p_1 p_2 + p_2^2)) + (\frac{(2 m/3 + g)}{2}) (p_2 (2 p_1 p_2 + p_2^2)) + (\frac{(m/2 + g)}{2}) (p_3 (2 p_1 p_2 + p_2^2)) + (\frac{(m + g)}{2}) (p_1 (2 p_1 p_3 + 2 p_2 p_3 + p_3^2)) + (\frac{(2 m/3 + g)}{2}) (p_2 (2 p_1 p_3 + 2 p_2 p_3 + p_3^2)) + (\frac{(m/2 + g)}{2}) (p_3 (2 p_1 p_3 + 2 p_2 p_3 + p_3^2))$$

Now the system of 3 equations that provides the equilibrium solution is:

$$EV(c/2) - EV(0) = 0$$
$$EV(c) - EV(c/2) = 0$$
$$p_1 + p_2 + p_3 = 1$$
Appendix 2: Instructions for Subjects

Section 2.1: Same-Function Alliance with equal profit-sharing arrangement

You will participate today in a decision making experiment concerning competition between two alliances (groups of firms). Each alliance is comprised of two partners.

We are interested in studying how two alliances compete with each other in the development of a new product. We are simulating this common situation in the laboratory. You will represent a firm, which is a member of one of the competing alliances. Three other subjects will represent the other three firms (the other member of your alliance and the two firms in the competing alliance).

The experiment involves many trials, and all of them have the same structure. At the beginning of each trial, you will be provided with some investment capital and then asked how much of it you wish to invest in the new product development project. The other three firms (the other member of your alliance and the two firms in the competing alliance) will also be provided the same amount of investment capital and asked to make similar investment decisions.

The rules of this investment game are simple. The capital invested by each firm in the development of the new product is non-recoverable. Therefore once invested the money is lost irrespective of the outcome of the competition. The alliance that invests more capital in the product development research will succeed in developing the new product, and each member of the winning alliance will receive a fixed reward. The reward does not depend on the relative investments made by each member of the winning alliance, so both the members of the alliance will receive the same fixed reward. The fixed reward represents profit that each member of the successful alliance earns from marketing the new product. Each member of the losing alliance receives nothing.

Experimental Procedure: As discussed above, there are 2 groups of firms (alliances), and each group is comprised of two players (members). At the beginning of each trial each player will be given some investment capital. All the players will receive the same investment capital and it remains unchanged from trial to trial. The investment capital will be stated in terms of a fictitious currency called “francs”, and at the end of the experiment your earnings will be converted to US dollars.

Once each player is allotted (endowed) some investment capital, he/she must decide how much to invest in his/her group’s new product development research. You may invest any number of francs (including zero), provided your investment does not exceed your endowment (investment capital allotted for the trial). After all the four players have made their investment decisions, privately and anonymously, the computer will compare the total investments made by the two groups of players. Members of the group that invests the larger amount will succeed in developing the new technology product, and they will receive a reward of known size (in francs). Members of the losing group will receive nothing. In this game ties will be counted as loses, as no alliance can be
considered a winner. In other words, if the investments made by both groups are equal, then no reward will be given to any of the four players.

As you can see from the game description, the individual payoffs for a trial are computed as follows:

Payoff to a member of the winning group = endowment for the trial - investment made by the firm in the trial + reward

Payoff to a member of the losing group = endowment for the trial - investment made by the firm in the trial

At the end of each trial the computer will display the following information:

1) The total investments made by the winning and the losing groups
2) The group winning the competition.
3) Your payoff for the trial.

It is important to note that only you know your investment decisions, and you are taking these decisions under complete anonymity. Group membership will vary from trial to trial. On each trial you will be paired with a different person in this room, and both of you will compete as a group against another new group of two players.

We are providing below an example to help you understand how your payoff is computed at the end of each trial.

**Example:** Suppose the capital endowed to each subject at the beginning of a trial is 2 francs, and the reward for winning the competition is 3 francs to each member of the successful group. Also suppose that you invest 2 francs and your partner invests 1 franc in the new product development research. Let the other group of players make a total investment of 2 francs in the development of their new product. Your group has invested more for developing the new product, so your group wins the competition. Each member of your group gets a reward of 3 francs.

Your payoff in this trial will be:

Your payoff = endowment - your investment + reward = 2 - 2 + 3 = 3 francs.

Your partner’s payoff = endowment - your partner’s investment + reward

= 2 - 1 + 3 = 4 francs.

Now imagine that the other group of players, who are competing against your group, invest 3 francs as well. In this case there is a tie and the reward will not be awarded to members of either groups. Your payoff in case of a tie will be as follows:

Your payoff = endowment - your investment + reward = 2 - 2 + 0 = 0 francs.

Your partner’s payoff = endowment - your partner’s investment + reward

= 2 - 1 + 0 = 1 francs.

This concludes the description of the decision task ahead of you. Paper and pencil are placed beside the computer terminal so that you may record the investments made by your group and the
other group. At the end of the experiment, your accumulated payoff will be converted to US dollars at the conversion rate of 100 francs = 3 dollars. You will be asked to sign a receipt for the money, and complete a brief questionnaire before leaving the lab. We are required to retain some biographical information about you, as we are paying you for participating in this experiment. However, during the course of this experiment you will remain anonymous. If you have any questions, please raise your hand and the supervisor will assist you.

After all the participants have understood the instructions, we will start the computerized experiment. In order to help you become familiar with the decision task, you will go through five practice trials.

Section 2.2: Same-function alliance with proportional profit sharing

You will participate today in a decision making experiment concerning competition between two alliances (groups of firms). Each alliance is comprised of two partners.

We are interested in studying how two alliances compete with each other in the development of a new product. We are simulating this common situation in the laboratory. You will represent a firm, which is a member of one of the competing alliances. Three other subjects will represent the other three firms (the other member of your alliance and the two firms in the competing alliance).

The experiment involves many trials, and all of them have the same structure. At the beginning of each trial, you will be provided with some investment capital and then asked how much of it you wish to invest in the new product development project. The other three firms (the other member of your alliance and the two firms in the competing alliance) will also be provided the same amount of investment capital and asked to make similar investment decisions.

The rules of this investment game are simple. The capital invested by each firm in the development of the new product is non-recoverable. Therefore, once invested the money is lost irrespective of the outcome of the competition. The alliance that invests more capital in the product development research will succeed in developing the new product, and the winning alliance will receive a fixed reward. The fixed reward represents the profit that the successful alliance earns from marketing the new product. The members of the winning alliance will share the reward in proportion to their investments in the development of the new product. So the member of the winning alliance who invests more will get a larger share of the fixed reward. Each member of the losing alliance receives nothing.

Experimental Procedure: As discussed above, there are 2 groups of firms (alliances), and each group is comprised of two players (members). At the beginning of each trial each player will be given some investment capital. All the players will receive the same investment capital and it remains unchanged from trial to trial. The investment capital will be stated in terms of a fictitious currency called “francs”, and at the end of the experiment your earnings will be converted to US dollars.
Once each player is allotted (endowed) some investment capital, he/she must decide how much to invest in his/her group’s new product development research. You may invest any number of francs (including zero), provided your investment does not exceed your endowment (investment capital allotted for the trial). After all the four players have made their investment decisions, privately and anonymously, the computer will compare the total investments made by the two groups of players. The group that invests the larger amount will succeed in developing the new technology product, and it will receive a reward of known size (in francs). The members of the winning group will share the reward in proportion to their relative investments. The losing group will receive nothing. In the case of ties, both groups will receive nothing.

As you can see from the game description, the individual payoffs for a trial are computed as follows:

Payoff to a member of the winning group = endowment for the trial
- investment made by the firm in the trial
+ reward (investment made by the firm in the trial / total investment of the winning alliance)

Payoff to a member of the losing group = endowment for the trial
- investment made by the firm in the trial

At the end of each trial the computer will display the following information:
1) The total investments made by the winning and the losing groups
2) The group winning the competition,
3) Your payoff for the trial.

It is important to note that only you know your investment decisions, and you are taking these decisions under complete anonymity. Group membership will vary from trial to trial. On each trial you will be paired with a different person in this room, and both of you will compete as a group against another new group of two players.

We are providing below an example to help you understand how your payoff is computed at the end of each trial.

Example: Suppose the capital endowed to each subject at the beginning of a trial is 2 francs, and the reward for winning the competition is 6 francs. Also now suppose that you invest 2 francs and your partner invests 1 franc in the new product development research. Let the other group of players make a total investment of 2 francs in the development of their new product. Your group has invested more for developing the new product, so your group wins the competition and your group gets the reward of 6 francs. The payoff for the members of your group in this trial is as follows:

Your payoff = your endowment for the trial
- your investment in the trial
+ reward (your investment / total investment of your alliance)
= 2 - 2 + 6 (2/3)  
= 4 francs.

Your partner's payoff = your partner's endowment for the trial
- your partner's investment in the trial
+ reward (your partner's investment / total investment of your alliance)
= 2 - 1 + 6 (1/3)
= 3 francs.

Now imagine that the other group of players, who are competing against your group, invest 3 francs as well. In this case there is a tie and both the groups do not get any reward. The payoff in the case of a tie will be as follows:

Your payoff = your endowment - your investment + reward = 2 - 2 + 0 = 0 francs.

Your partner's payoff = your partner's endowment - your partner's investment + reward
= 2 - 1 + 0 = 1 francs.

This concludes the description of the decision task ahead of you. Paper and pencil are placed beside the computer terminal so that you may record the investments made by your group and the other group. At the end of the experiment, your accumulated payoff will be converted to US dollars at the conversion rate of 100 francs = 3 dollars. You will be asked to sign a receipt for the money, and complete a brief questionnaire before leaving the lab. We are required to retain some biographical information about you, as we are paying you for participating in this experiment. However, during the course of this experiment you will remain anonymous. If you have any questions, please raise your hand and the supervisor will assist you.

After all the participants have understood the instructions, we will start the computerized experiment. In order to help you become familiar with the decision task, you will go through five practice trials.

Section 2.3: Parallel development of new products with equal profit-sharing arrangement

You will participate today in a decision making experiment concerning competition between two alliances (groups of firms). Each alliance is comprised of two partners.

We are interested in studying how two alliances compete with each other in the development of a new product. We are simulating this common situation in the laboratory. You will represent a firm, which is a member of one of the competing alliances. Three other subjects will represent the other three firms (the other member of your alliance and the two firms in the competing alliance).

The experiment involves many trials, and all of them have the same structure. At the beginning of each trial, you will be provided with some investment capital and then asked how much
of it you wish to invest in the new product development project. The other three firms (the other member of your alliance and the two firms in the competing alliance) will also be provided the same amount of investment capital and asked to make similar investment decisions.

The rules of this investment game are simple. The capital invested by each firm in the development of the new product is non-recoverable. Therefore once invested the money is lost irrespective of the outcome of the competition. The utility (value) of the new product developed by an alliance depends on the maximum investment made by a partner in the alliance. For example, if the partners A and B in an alliance invest 2 and 1 units of resources respectively for developing the new product then the utility of the new product so developed will be 2 utils. The alliance offering the better product will win the competition, and each member of the winning alliance will receive a fixed reward. The reward does not depend on the relative investments made by each member of the winning alliance, so both the members of the alliance will receive the same fixed reward. The fixed reward represents profit that each member of the successful alliance earns from marketing the new product. Each member of the losing alliance receives nothing.

Experimental Procedure: As discussed above, there are 2 groups of firms (alliances), and each group is comprised of two players (members). At the beginning of each trial each player will be given some investment capital. All the players will receive the same investment capital and it remains unchanged from trial to trial. The investment capital will be stated in terms of a fictitious currency called “francs”, and at the end of the experiment your earnings will be converted to US dollars.

Once each player is allotted (endowed) some investment capital, he/she must decide how much to invest in his/her group’s new product development research. You may invest any number of francs (including zero), provided your investment does not exceed your endowment (investment capital allotted for the trial). After all the four players have made their investment decisions, privately and anonymously, the computer will compute the value of the new product developed by each of the two competing alliances. The utility (value) of the new product developed by an alliance depends on the maximum investment made by a partner in the alliance. The alliance offering a better product will win the competition. Members of the winning alliance will receive a reward of known size (in francs). Members of the losing group will receive nothing. In this game ties will be counted as loses, as no alliance can be considered a winner. In other words, if the maximum investments made by both groups are equal, then no reward will be given to any of the four players.

As you can see from the game description, the individual payoffs for a trial are computed as follows:
Payoff to a member of the winning group = endowment for the trial - investment made by
the firm in the trial + reward
Payoff to a member of the losing group = endowment for the trial - investment made by
the firm in the trial

At the end of each trial the computer will display the following information:

1) The total investments made by the winning and the losing groups
2) The group winning the competition,
3) Your payoff for the trial.

It is important to note that only you know your investment decisions, and you are taking these decisions under complete anonymity. Group membership will vary from trial to trial. On each trial you will be paired with a different person in this room, and both of you will compete as a group against another new group of two players.

We are providing below an example to help you understand how your payoff is computed at the end of each trial.

Example: Suppose the capital endowed to each subject at the beginning of a trial is 2 francs, and the reward for winning the competition is 3 francs to each member of the successful group. Also suppose that you invest 2 francs and your partner invests 1 franc in the new product development research. The maximum investment made by your group is 2 francs, and the value of the new product developed by your group is 2 utilis. Let each player in the competing alliance make an investment of 1 franc each. The competing alliance has made a maximum investment of 1 franc, and the value of the new product developed by the competing alliance is 1 util. So your group has developed a better and it wins the competition. Each member of your group gets a reward of 3 francs each.

Your payoff in this trial will be:

Your payoff = endowment - your investment + reward = 2 - 2 + 3 = 3 francs.

Your partner’s payoff = endowment - your partner’s investment + reward

= 2 - 1 + 3 = 4 francs

Now imagine that the two players in the competing alliance invest 2 francs each. So the value of the new product so developed by the competing alliance is 2 utilis. In this case there is a tie and the reward will not be awarded to members of either groups. Your payoff in case of a tie will be as follows:

Your payoff = endowment - your investment + reward = 2 - 2 + 0 = 0 francs.

Your partner’s payoff = endowment - your partner’s investment + reward

= 2 - 1 + 0 = 1 franc.

This concludes the description of the decision task ahead of you. Paper and pencil are placed beside the computer terminal so that you may record the investments made by your group and the other group. At the end of the experiment, your accumulated payoff will be converted to US dollars at the conversion rate of 100 francs = 3 dollars. You will be asked to sign a receipt for the money, and complete a brief questionnaire before leaving the lab. We are required to retain some biographical information about you, as we are paying you for participating in this experiment.
However, during the course of this experiment you will remain anonymous. If you have any questions, please raise your hand and the supervisor will assist you.

After all the participants have understood the instructions, we will start the computerized experiment. In order to help you become familiar with the decision task, you will go through five practice trials.
Figure 1A: Same-Function Alliance
Investment Pattern under Equal Profit-Sharing Arrangement
\((g=0, s=0)\)

Figure 1B: Same-Function Alliance
Investment Pattern under Proportional Profit-Sharing Arrangement
\((g=0, s=0)\)

Figure 1C: Same-Function Alliance
Effect of Profit-Sharing Arrangement
(Mean investment under equal and proportional Profit Sharing)
Figure 2A: Parallel Development
Investment Pattern under Equal Profit-Sharing Arrangement
\( (g=0, \ s=0) \)

Figure 2B: Parallel Development
Investment Pattern under Proportional Profit-Sharing
\( (g=0, \ s=0) \)
Figure 3A: Effect of Type of Alliance
Comparison of investment when profits are shared equally

- Parallel Development
- Same-Function

Figure 3B: Effect of Type of Alliance
Comparison of mean investment when profits are shared proportionally

- Parallel Development
- Same-Function

Figure 3C: Parallel Development
Effect of Profit-Sharing Arrangement
Comparison of mean investments

- Proportional
- Equal
Figure 4A: Same-Function Alliance
Empirical Distribution of Strategies
(Equal profit sharing, high reward condition)

Figure 4B: Same-Function Alliance
Empirical Distribution of Strategies
(Equal profit sharing, medium reward condition)

Figure 4C: Same-Function Alliance
Empirical Distribution of Strategies
(Equal profit sharing, low reward condition)

Note: The empirical distribution was computed across subjects in blocks of 10 trials
Figure 5A: Same-Function Alliance
Empirical Distribution of Strategies
(Proportional profit sharing, high reward condition)

Figure 5B: Same-Function Alliance
Empirical Distribution of Strategies
(Proportional profit-sharing, medium reward)

Figure 5C: Same-Function Alliance
Empirical Distribution of Strategies
(Proportional profit sharing, low reward condition)

Note: The empirical distribution was computed across subjects in blocks of 10 trials.
Figure 6A: Parallel Development
Empirical Distribution of Strategies
(Equal profit sharing, high reward condition)

Figure 6B: Parallel Development
Empirical Distribution of Strategies
(Equal profit sharing, medium reward condition)

Figure 6C: Parallel Development
Empirical Distribution of Strategies
(Equal profit sharing, low reward condition)

Note: The empirical distribution was computed across subjects in blocks of 10 trials
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