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STRATEGIC ALLIANCES AND FIRM GROWTH IN SCHUMPETERIAN COMPETITION

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Abstract

This paper utilizes a computer simulation model to examine whether cost-sharing R&D alliances are conducive to long-term survival of the partners under the increasing-returns regime of Shumpeterian competition. Despite a recent surge of interest on strategic alliances, there is still little understanding of long-term gains in R&D alliances. The simulation results present a surprising outcome that casts doubt on the long-term attractiveness of alliances compared to independent research. Managing innovations through strategic alliances appears to be a losing game, particularly when the primary motive of collaboration is to share costs. Collaborating firms are less likely to survive than non-collaborating firms at least in the long run due to the welfare loss and conflicts between partners. Collaborative research offers advantage only when the welfare loss and alliance costs become very small. The simulation results confirm that long-term outcomes of strategic alliances, in particular cost-saving alliances, depend on successful management of conflicts that arise in the process of collaboration.

Key Words: Strategic alliances
Schumpeterian competition
Firm growth

INTRODUCTION

Traditionally, R&D activities and innovations were carried out independently by firms. Neoclassical economics and traditional approaches to strategic management have stressed the values of pluralism and rivalry as the best approach to promote organizational innovation. Schumpeter (1934) claimed that only large, internalized firms can afford innovation because of high R&D costs and the need to control early product markets to recoup them. Firms have also considered interfirm collaboration with reluctance, finding them a second-best option to direct competition in the open market (Van de Ven & Walker, 1984; Mowery et al., 1996).

In recent years, however, innovation has become more difficult and risky for independent firms because of excessive costs and higher uncertainty and complexity in managing the process (Powell, 1990). Increasingly, strategic alliances are thought to enhance innovative capabilities of firms by providing opportunities for shared learning, transfer of technical knowledge, legitimacy, resource exchange, and cost sharing (Nohria & Eccles, 1992). Moreover, the new global competition has raised the standards for quality, innovation, productivity and customer value to such a high level that individual firms find it difficult to compete alone. Alliances are now acclaimed as a critical mechanism to compete in the global market and to cope with the rapid pace of technological advancement (Harrigan, 1986). Indeed, the incidences of strategic alliances have increased dramatically since the early 1980s, with a majority of them concentrated in technology intensive industries where R&D capabilities are a key element of competitive advantage (Krubsik & Lautenschlager, 1993; Powell et al., 1996). Today, it has become common even for rivals to form an alliance for joint research and development.

The increasing popularity of alliances has resulted in a new view in the field that strategic alliances are an inevitable strategic choice for survival as firms experience an unprecedented technological race in R&D intensive industries. This imperative view of alliance focuses mostly on the potential benefits of interfirm collaboration such as cost sharing, risk reduction, and access to complementary assets (Ohmae, 1989; Kogut, 1991). Studies supporting this line of view focus mostly on short-term benefits of alliances and imply that strategic alliances are also conducive to the long-run survival of firms in risky and uncertain business settings. However, there has been no concrete empirical evidence yet that supports the long-term contribution of alliances to firm survival.

Despite the purported benefits, strategic alliances and other forms of interfirm collaboration are seen as risky and highly unstable (Park & Russo, 1996). Several studies have set the rate of alliance failure at as high as 7 in 10 (Coopers & Lybrand, 1986), 2 in 3 (Kogut, 1991) and 1 in 2 (Harrigan, 1988). Other adverse effects of alliance failure have been identified in comparable of competitive alliances. Partners, particularly U.S. partners in cross-border alliances, tend to suffer serious losses due to the involuntary loss of potential revenue (i.e., economic rents) and the uncompensated transfer of rent-generating resources, such as technology (Hamel et al., 1989). While firms form alliances with expectations of various benefits including cost sharing and reduced rivalry, such competitive forces cannot be completely redressed and persist as potential sources of conflict. Firms should bring in the necessary assets to the alliance to accomplish the acclaimed collective goal and share with partners the rewards from the innovation. As they do so, they should also be aware of the competitive standing and protecting the basis of their competitive advantages. Given the implicit competition within an alliance, it becomes highly complex for partners to allocate their contribution and to distribute the innovative payoffs ex post, which often triggers serious conflicts and subsequent welfare losses in the alliance. This is why some argue that the benefits of cross-firm innovations have been overemphasized and that alliances frequently result in unplanned divestitures (Park & Russo, 1996; Bleeke & Ernst, 1995). Due to this potential danger and cost of alliances, some even argue that the recent surge of interest in alliances is a temporary managerial fad with no substantial gains (e.g., Gomes-Casseres, 1993).

Is the rise of strategic alliances simply a fad that will taper off eventually, or an inevitable strategic choice for the long-term survival of the firm facing an ever-enhancing technological race? Studies have shown various evidences supporting both lines of thought, but they have been either fragmented or focused only on short-term outcomes of alliances. Resolving this issue requires a systematic analysis of long-term outcomes, e.g., survival, of strategic alliances to participating firms. The paucity of research on this issue is mainly due to the nature of the research issue that cannot be easily addressed by empiricists. It is impossible to conduct empirical testing of the effect of alliance strategy on firm survival given that the alliance is only one of the many factors that contribute to survival or dissolution of a firm. Another constraint in studying the issue is the limited window of observation. While the strategic alliance still has a short history of operation, understanding the long-term effect of alliances on firm survival requires a longitudinal study. Given these research constraints, this study utilizes a computer simulation model to examine the issue, which allow us to conduct a long-term assessment of dynamic effects of R&D alliances on firm survival.

Our model adopts the Schumpeterian competition as the underlying mechanism of the market. Under the Schumpeterian competition, competitors put pressure on innovators to develop new products through their imitative and innovative threats, leading to high R&D expenses for innovators. This is well illustrated by the continuous increase in R&D costs in pharmaceutical and semiconductor industries. In particular, our model is based on a dynamic Schumpeterian context where increasing returns characterize the innovation race and where small effects create strong path dependency over time (Nelson & Winter, 1982). Would benefits of R&D alliances be able to eventually offset costs under this dynamic regime of increasing returns?

The results in our computer simulation indicate that alliance costs overshadow the benefits from collaborative research at least in the long run. Under various parametric conditions, strategic alliances specifically designed for cost sharing appear to be a losing strategy in the long run compared to in-house, i.e., independent, management of innovations. The strategic alliance seems to be a reasonable choice only when the potential conflicts between partners could be minimized. These results are highly consistent with earlier findings in the alliance literature that show both benefits and costs of interfirm collaboration.

In the following section, we first characterize Schumpeterian competition and review the literature for costs and benefits of alliances. Then, we develop a dynamic model of Schumpeterian competition that incorporates two innovation strategies -- alliance-based R&D vs. independent R&D. The paper concludes with several implications of the simulation results in relation with long-term outcomes of R&D alliances.

SCHUMPETERIAN COMPETITION AND STRATEGIC ALLIANCES

Interfirm collaboration is not a new phenomenon, in particular in the international business area (Harrigan, 1986). What distinguishes the recent trend from the old practices is the unprecedented intensity in alliance formation and the shift in motives that often involve direct competitors. In technology-intensive industries, e.g., semiconductors, computers, software, and commercial aircraft, the rate of alliance formation has increased significantly and alliances have become wide spread only over the last two decades. Mowery et al. (1996) noted that strategic alliances were of little or no importance prior to 1975 in these high technology industries.

Moreover, these recent alliances for joint R&D and product development involve higher levels of knowledge exchange and technology transfer among participants (Mowery et al., 1996). Krubsik and Lautenschlager (1993) also indicate a similar trend in alliance formation in high-tech industries. They point out that there has been as much as a fourfold annual increase of alliances in technology-intensive industries such as electronics, pharmaceuticals, and computers.

The Schumpeterian competitive framework reflects competitive dynamics in these types of technology-intensive industries, posing it as a proper framework to assess long-term dynamic effects of alliances. The essence of Schumpeterian competition is the evolution of a market through "competitive elimination of the old" (Schumpeter, 1934: 67). Of special interest to this study is competition through product innovations in a multiple product industry.

The two main drivers in Schumpeterian competition that challenge and replace the existing basis of firm competence and survival are competitors' innovation and imitation (Nelson and Winter, 1982). When competition is based on new product development, the threatening forces of innovation and imitation tend to limit the time windows for existing products that serve as ammunition for innovators to stay in an innovative battle. Imitation erodes the innovators' Schumpeterian rents from their existing products. New products introduced by competing innovators also randomly replace existing products. Facing these twin Schumpeterian threats, innovators are under the pressure of routinely searching for new products, which is the only avenue to escape from the perennial selection pressure of Schumpeterian competition. These competitive challenges and the innovators' response, i.e., routinized search for new products, create a constant motion in the system unless technological opportunities become depleted.

Thus far, most evolutionary models have focused only on an independent search within the boundary of a firm. As Baumol (1993: 194) pointed out, the Schumpeterian models took the conventional view of the firm as "zealous guardians of the proprietary innovations in their possession." Indeed, such proprietary features have been conceived to prolong a differential advantage in the game of the survival of the fittest. It then appears that voluntary information exchange arrangements across the firm boundary are at odds with this line of evolutionary view. However, we argue that this is not the case because the basic tenet of searching for new ways of surviving the perennial pressing condition remains intact regardless of whether it is sought by firms independently or through alliances. Interfirm alliances can easily be subsumed under the existing evolutionary view as long as the unit of search is shifted from the firm to interfirm relations.

THE MODEL

Increasing Returns Regime Our model is characterized by dynamic increasing returns and shares several analytical similarities with Nelson and Winter's Schumpeterian models (1978; 1982). In an increasing returns regime size confers a dynamic advantage to firms. It is assumed that large firms allocate more R&D expenditures than small firms and the amount of R&D expenditure is associated with a higher probability of innovation success. Thus, once a firm succeeds in its innovation by chance, it is more likely to do so over time as capital accumulates from a series of success.

Figure 1 illustrates the increasing returns feature of our model, with the average capital of firms growing exponentially over time. The higher the success probability of an innovation, the more pronounced is the pattern of exponential growth. Figure 2 also captures another sign of increasing returns, with the number of products increasing over time while the number of firms decreasing constantly in the market. In this framework, once a firm makes the initial success by chance, it tends to grow faster and get larger and larger. This coincides with Nelson and Winter's view (1982: 325) that "growth confers advantages that make further success more likely." A typical pattern in this evolutionary process is the emergence of giant firms and a self-sustaining innovative regime as they become more resilient to countervailing forces. Lee's recent historical study of the U.S. pharmaceutical industry provides an empirical correspondence to this process (Lee, 1998). Given this attribute as the underlying dynamics of the model, we attempt to explore whether the early positive effect of forming alliances gets magnified over time and translates into a long-term advantage.

Place Figure 1 & 2 About Here

Benefits and Costs of Strategic Alliances Previous studies suggest several benefits of strategic alliances especially in surviving a technological race of Schumpeterian competition. Some of the potential benefits and motives of technology alliances are spreading costs and risks of innovation, obtaining access to new markets and technologies, expediting the commercialization process, pooling and learning complementary skills, and so on (Kogut, 1989; Kleinknecht & Reijnen, 1992; Hagedoorn, 1993; Powell et al, 1996). Moreover, these benefits are considered to be conducive to the long-term survival of the firm. Gulati (1995) notes that it is crucial for success and survival for firms to be placed within a network of interorganizational relationships as the alliance strategy continues to proliferate among competitors.

It is a daunting task to develop a dynamic model that incorporates these multiple elements of alliance formation. This is not because it is impossible to develop a complex numerical model but because it is difficult to comprehend the outcomes of the model when so many elements operate simultaneously over a long time period. Our model addresses only one benefit of the strategic alliance, i.e., cost sharing, to keep the model simple and comprehensible. In Schumpeterian competition firm resources are limited to developing several new products of which only a few offer growth opportunities. Survival of the firm depends on who finds these opportunities first and exploits them fully before they fade away. In this evolutionary process, strategic alliances are used as a strategic mechanism to overcome the limitation in an individual search and to increase the firm's search possibilities. Indeed, Kogut (1991) states that strategic alliances, e.g., joint ventures, serve as an attractive mechanism to invest in an option to expand in risky markets due to the benefits of sharing risks and of reducing overall investment costs.

The following simple analogy captures the essence of strategic alliances in Schumpeterian competition we consider in this paper. Let's suppose that a gambler has a limited amount of money, e.g., $10, and that each trial in a slot machine costs $1. When the gambler plays the slot machine alone, it takes ten trials for him/her to run out of money unless some of them return a reward. On the other hand, if the gambler can share the capital with another person with same amount of initial capital, the minimum number of trials to win a prize doubles. Our question is whether increasing the search possibilities by pooling the investment with a partner has a positive effect on the survival of the firm in an increasing returns regime of Schumpeterian competition.

Although the number of alliance formation has increased dramatically in recent years, some say success has become an exception rather than a rule (Parkhe, 1993; Park & Russo, 1996). A search through interfirm collaboration incurs costs that could be avoided if it is carried out alone. Conflicts in interfirm arrangements arise as participants share rewards from the innovation. Allocating the rewards, however, often become arbitrary due to the uncertainty in the outcome of innovations and in sorting out each partner's contribution. In general, collaborative arrangements beyond the boundary of a firm create a concern in allocating payoffs from the collaboration. If participants have perfect information about the outcome of the collaborative innovation, it is possible to make the payoff explicit ex ante. However, this is usually not the case especially when market competition is based on innovation. Indeed, one critical underlying assumption in a neo-Schumpeterian framework is the presence of uncertainty.

Innovation alliances often work better when partners are in a complementary position as opposed to a substitute position (Baumol, 1993; Park & Russo, 1996). However, it is highly ambiguous to draw such a line as market boundaries and business domains of the firm are constantly evolving. In this type of market setting, there is even competitive confusion about who is an ally and who is not (Powell et al., 1996). The evolution of the PC industry illustrates this well. Microsoft was a fledgling supplier of an operating system, MS-DOS, when IBM entered the PC industry. The relationship between the two could have been easily seen as a complementary alliance at least at the early stage of the industry. Yet, the industry evolution shows that Microsoft became a major beneficiary of the alliance whereas its partner, i.e., IBM, turned out to be a victim in the end (Chesbrough & Teece, 1996).

Consider a case of a generic alliance that two potential competitors decide to cooperate at an early stage of innovation, even after realizing that they might compete with each other at some later stage. Nevertheless, their decision to cooperate is based on the expectation that, in the long run, benefits will outweigh costs of the collaboration. However, both parties know that the current intention by itself is insufficient, for, once completed, they could act opportunistically by withholding important information, providing false information, or simply cheating the other. Moreover, the sheer complexity of the alliance might preclude the partners from evaluating their contributions over time, leading to perceptions that their contributions are unbalanced and asymmetric. Even trust and commitment between partners are tempered by perceptions of gains-or-losses, equity considerations, procedures to assess balanced contributions, goal conflicts, and role ambiguities.

Game theoretic models have been used to illustrate how an innovation alliance could affect post-innovation payoffs for partners (Abreu et al., 1991). The model presents two polar scenarios: One possibility is that each partner has a strong incentive to keep the results of the collaborative R&D proprietary while damaging the relationship. In this case, it is possible that the alliance will be terminated prematurely or become ineffective to accomplish potential benefits as described above while having wasted lots of time and resources for the participants. This also results in a welfare loss due to under-utilization of the full potential of interfirm collaboration. Other possibility is that partners start out fully engaging in the collaborative effort based on trust, which can bring in the realization of most of potential benefits. This is the best way to minimize the welfare loss, but given the complexity and uncertainty in collaborative innovation, it is difficult to foresee this type of situation easily. In fact, R&D alliances encompass "a multiplicity of possible asymptotic outcomes" where the destiny of such a dynamical system is unknown *ex ante* (Arthur et al, 1994: 33). It is always possible that firms may give away more than it receives through alliances unless there is enough caution. Reich and Mankin (1986) argue that Japanese firms' technological capabilities in many industries (e.g., the semiconductor industry) were largely built on U.S. technologies acquired through various strategic alliances. In the 1980s several Japanese firms emerged as winners while many American partners lost their leadership positions.

Are there enough long-term gains for partners to offset these potential costs and welfare loss? Given these potential problems in interfirm collaboration, some suggest that the recent popularity of strategic alliances are nothing more than reflecting a bandwagon effect in corporate strategies (Venktraman et al., 1994) or the quest for firm legitimacy (Sharfaman et al., 1991; Baum & Oliever, 1991).

Would firms form R&D alliances at the absence of survival pressure? How would the assets and liabilities that occur in R&D alliances affect the dynamic and pressuring conditions in an innovation race? Informal and anecdotal evidences may help us identify environmental factors and firm imperatives for the proliferation of R&D alliances, but such untutored intuition easily misleads us to hasty conclusions about the dynamic and complex system in the evolution of firms and markets. Informal stories often skip some obvious and important steps and fail to offer a systematic approach to detect these missing logical elements. The following simulation model offers a preliminary step to systematically explore the evolutionary issue on alliance formation and firm growth by utilizing a dynamic Schumpeterian competition model.

The Model The simulated model reflects a stylized evolution of a multi-product industry. In this setting firm competition focuses on developing new products, and firms with innovative products continuously prosper while firms that fail to innovate decline and may exit from the market. This follows a similar logic as Nelson and Winter (1982) that characterizes the evolutionary process according to a size-dependent and stochastic growth process. Our model features firms as innovators while controlling for competitive imitation through a system parameter. For simplicity, the model rules out entry over time.

Firm Growth and Exit In the model, the process of growth and decline in firm capital is a characteristic feature of economic selection (Winter, 1971; Nelson & Winter, 1982). The following difference equation describes whether firm i grows or declines at time $t + 1$:

$$K_{it+1} = K_{it} - C_{it} + R_{it},$$

where K_{it}, C_{it}, and R_{it} represent firm i's capital, investment, and return at time t respectively. It is possible for the firm to continuously fail to innovate so that its capital stock becomes smaller than the minimum R&D cost, ω, that leads to exit of the firm. Both random and non-random factors affect the evolutionary process of growth and exit.

The relationship between firm size and R&D effort explain the non-random characteristic in the evolution. Firm size confers an advantage to firm innovation by increasing the success probability, which is a main departure from the Gibrat's law (Nelson and Winter, 1982). The larger the firm is, the more projects it can carry out for new product development, which increases the chance of having a new product. Let d_{it} be the number of firm i's development projects at time t. Assuming the indivisibility in organizing R&D, d_{it} becomes a step function of capital at t-1 with a discrete unit τ such that

$$d_{it}(K_{it-1}) = \begin{cases} 1 & \text{if } \omega \le K_{it-1} \le \tau, \\ 2 & \text{if } \tau < K_{it-1} \le 2\tau, \\ \vdots & \\ n & \text{if } (n-1)\tau < K_{it-1} \le n\tau. \end{cases}$$

Similarly, firm i's R&D cost at time t, C_{it}, increases as a multiple of ω as follows:

$$C_{it} = \omega\, d_{it}.$$

The model also incorporates the luck factor in the process of product development. Each trial of d_t has a success probability of p, which is assumed to be time-invariant. There is a stochastic element that allows the firm to fail to generate new products at time $t+1$ even when C_{it} is substantially large. When firm i successfully develops product j at time t, it receives a stream of payoff r_j in subsequent periods, i.e., t+1, t+2, ..., t+q.

There are two components of Schumpeterian competition that influence the life span, i.e., q, of product j and its return r_j. First, successful introduction of a new product k generates a time-constant return stream by creating a new niche, leaving j's current market intact. However, it is also capable of replacing the existing niche for product j. Suppose this probability is ρ_{jt}, which shapes the extent of creative destruction inherent in Schumpeterian competition.

Second, imitation also limits the time window, q, for product j's return r_j. A system parameter $\varphi \geq 1$ specifies the effect of imitative erosion in our model. Unless another new product replaces product j, its return is eroded by competitors, leaving $q = \varphi$. Let $\mathbf{P}_{it}$ be a set of firm i's products that have survived imitative erosion and innovative destruction, or that are newly introduced at time t. Then, firm i's total return at time t becomes:

$$R_{it} = \sum_{j \in \mathbf{P}_{it}} r_j$$

So far, the model features the evolutionary process of growth and exit as firms try to develop new products without forging alliances. The next section describes a process in which firms utilize strategic alliances as a strategic weapon to enhance the chance of successful innovation.

Increasing the Search Possibilities In our model, strategic alliances double the chance for searching new products for given resources. For example, at a minimum R&D cost, ω, a firm can carry out only one development project while an alliance allows the firm to carry out two projects, i.e., 2ω, by pooling their resources together. Given the stochastic process of success in innovation, increasing the search effort results in a higher chance of developing new products, which becomes the source of new revenue stream in the future.

In a typical neo-Schumpeterian model, the success probability of innovation depends on time and size (i.e., capital). A key to sustaining the alliance-based advantage is the linkage between the enhanced search efforts and the success probability in the long run. If this relationship is positive over time as the alliance literature advocates, the alliance-based innovation becomes a winning strategy under Schumpeterian competition. Thus, in the simulation we attempt to examine whether the alliance-based advantage is stochastically dominating over time.

Our model is also based on a dyadic alliance in which two firms contribute equally to the R&D cost, i.e., 0.5ω. The simplified partner selection process goes as follows. A pair of firms with largest capitals begins to form an alliance, which reduces their capitals by 0.5ω. Then, the next two largest firms form another alliance, which is repeated until the alliance options are exhausted. At the end of the process, leftover R&D budgets, if there is any, invest individually into product development. Thus, if firm i's capital is $(n-1)\tau < K_{it-1} \leq n\tau$, the number of development projects that the firm is capable of carrying out through alliances is between n and $2n$. The model is designed such that firms can find maximal alliance pairs among available firms in the market. An inefficient design of this process can easily lead to the worst scenario that no firms participate in alliance strategy even when there are more than two firms in the market. In this case, the alliance strategy is not different from the non-alliance situation where innovators pursue innovation individually. This maximal design of partner selection attempts to minimize potential confounding effects due to failure of the alliance market. This maximal control of the setting allows us to assess the logical consequence of alliances on firm survival. This simple process simulates a setting that experimenters can examine the pure effect of a variable of interest while controlling for unwanted variances.

Allocation of Payoffs The model incorporates two types of costs in a strategic alliance: An arbitrary allocation of payoffs from joint investment and a welfare loss due to undesirable conflicts between partners. The reward from collective innovation is not necessarily distributed evenly between partners. The distortion in the allocation process can be highly complex, which is treated as external to an implicit observer. Two random parameters reflect such arbitrariness in allocating the payoffs, i.e., θ and ζ. Let θ and $(1-\theta)$ be coefficients of allocation for the partners, where $\theta \in [0, 1]$. For a payoff r_j, the partners receive θr_j and $(1-\theta) r_j$. They will evenly share the return from the joint innovation if $\theta = (1-\theta) = 0.5$. Otherwise, one partner takes a bigger share of the payoff that the other, which is determined by a random number θ that follows normal distribution with a mean of 0.5 and a variance of σ^2.

Furthermore, if both partners attempt to keep the technological information proprietary, there will be a welfare loss such that the sum of a joint payoff becomes smaller than the full potential r_j. A realized collective payoff in the presence of such intention can be represented by ζr_j, where ζ follows a beta distribution with shape parameters α_1 and α_2. Then, the welfare loss is $(1-\zeta)r_j$. Given the joint investment held constant, random numbers θ and ζ affect the net payoff for each partner.

THE SIMULATION RESULTS

The simulation demonstrates numerically how the costs and benefits of strategic alliances affect growth and survival of the firm over time. We first explore the properties of the basic model. We then explore various variations in underlying conditions of the basic model and compare changes in these properties.

Basic Model The simulation begins with 1000 firms. One half of the firms choose to invest in R&D alone while the other half pursues alliance strategy with others. Our analysis focuses on comparative dynamics of two factors--the number of survivors and the intertemporal average capital--to illustrate the costs and benefits of R&D alliances and their effect on the evolution of industry. Figures 2, 3, and 4 show the results of typical simulation runs.

Figure 2 shows the number of products available in the market over time. Each number at a particular point in time reflects a sum of newly-introduced products and the old products that have not been subject to imitative erosion and innovative destruction up to the point. This number indicates survivors' sustaining power in tracking further innovations. Although the base line success probability is set to a constant ($p = 0.03$), the number of products increases over time, suggesting that the innovative regime in the model can self-sustain while many failing firms exit the market. This self-sustainability of the market reflects dynamic increasing returns in the model (see Figure 1).

Place Figures 3 and 4 About Here

Figure 3 shows the evolution of two groups of firms. For the firms pursuing R&D individually, the number of survivors suddenly drops from 500 to 219 in simulation year 14 while it does so to 348 for the firms pursuing the alliance strategy. The sudden drop reflects the departure of the firms that consistently failed to generate new products and ran out of their initial capital endowment. The difference in the number of survivors suggests that the alliance strategy is superior to independent R&D to overcome an initial hurdle of innovation. However, the mortality rate of the alliance group grows faster over time than that of the independent R&D group, eventually crossing each other as shown in Figure 3.

Why does the hazard for collaborative innovators grow faster over time? Figure 4 illustrates that it is due to the difference in capital growth between the two groups. Average capital grows much faster in the independent R&D group than in the alliance group, whose gap grows exponentially over time.

It is interesting to note the tradeoff between the two approaches. The benefit of an alliance by doubling the search possibility is realized in the short-run as shown in Figure 3. However, alliance participants have to share the payoff from successful innovations with their partners, which may cause a welfare loss, independent innovators do not bear this cost resulting in higher capital accumulation as long as they survive. Thus, it seems that the costs of interfirm collaboration offset over time the short-term gains from higher search possibilities. The next section explores whether this differential growth between the two groups of firms holds over diverse parametric conditions of alliance costs.

Simulation Experiment We reiterated the experiment by varying the condition of welfare loss from the basic model. The shape parameters α_1 and α_1 are varied from (1, 9) to (2, 8), (3, 7), ..., and (9, 1), which are equivalent to theoretical mean values of the welfare loss $(1-\zeta)$ that range from 0.1 to 0.9 in increments of 0.1. We explore the effects of benefits and costs of R&D alliances in diverse parametric settings by running each variation of the model hundred times to generate quasi-asymptotic outcomes.

Place Table 1 About Here

Table 1 and Figures 5 and 6 show results from these experiments. As the average proportion of loss increases, the number of survivors and the average size of capital in the alliance groups decrease toward the end of the simulation runs while they remain relatively constant for independent innovators. Only when the average loss is less than .2, the alliance group shows a larger number of survivors than the other independent group (see Figure 5). As the average value of loss increases, the number of survivors decreases much faster and approaches zero for the alliance group. Figure 6, however, shows that the non-alliance group constantly outperforms the alliance group in all range of the parameter for the average accumulated capital.

Place Figure 5 & 6 About Here

Figures 7 and 8 show the overall landscape for the alliance group in terms of the accumulated capital and the number of survivors in reference to time and average loss. The height at a specific point represents the survival value in terms of average capital or average survival rate. These landscapes confirm the results in Figures 5 and 6 suggesting that the alliance strategy would work well only within a limited region of small welfare loss.

Place Figure 7 & 8 About Here

DISCUSSION

Over the last two decades as markets continue to globalize and experience faster technological changes, the belief that interfirm collaboration has more advantages over outright competition has gained much popularity. Within this emerging perspective, collaborative research is heralded as an alternative mode of conduct among competitors. Along with various benefits of strategic alliances, however, a prominent theme in the literature has been the difficulties in managing interfirm collaboration and the dangers in coordinating with potential competitors. While a good number of studies have addressed the benefits and costs in interfirm collaboration, there is yet no empirical evidence about the long-term outcomes of R&D alliances on firm survival and growth. This study applies a simulation analysis to explore whether research alliances confer competitive advantages to participants under Schumpeterian competition where the basis of firm survival and leadership is constantly challenged by innovative destruction and imitative erosion.

The key finding in our study is that increasing the search possibilities through strategic alliances helps firms reduce the innovation risk in the short run, but such gain is not necessarily warranted in the long run. The welfare loss and conflicts in sharing the payoff seem to slow down capital accumulation from successful innovations. Such a delay is critical to firm survival because the key to staying in an innovative race of Schumpeterian competition is to reach the necessary threshold in size early on (Lee, 1998). Surprisingly, the simulation results indicate that the long-term gains from strategic alliances are not as great as many advocates suggested while there is potentially a substantial loss under the pressing technology race. The cost-sharing R&D alliance seems to be a winning strategy only when the welfare loss from interfirm conflict is minimal; otherwise, it is a losing strategy in the long run in terms of firm survival and growth. This finding reiterates the potential conflicts and dangers of strategic alliances at least in the long run. Gomes-Casseres (1993) also observed that the previous boom in alliance activity has been followed by disappointment with its results and by a period of consolidation, particularly when firms were less anxious to expand their alliance networks, or even shrunk them.

However, there is a caution in interpreting our findings. In no way this study attempts to generalize the findings beyond the settings simulated in the model. Our model reflects only one type of many potential benefits of alliances, i.e., cost-sharing in R&D alliances. R&D alliances offer other valuable advantages other than cost-sharing to participants, such as access to complementary advantages and learning that would not happen as firms operate alone. This study, however, presents a conservative case or a lower bound in understanding the benefits of strategic alliances. We hope this study paves the way for future studies to explore long-term effects of strategic alliances on firm growth. It would be interesting to see how the results in this study would change as studies incorporate new parametric settings and construct an alternative dynamic mechanism. Indeed, one may consider our model (and findings) as a baseline case that serves as a target to reject in future studies as they build on to the model by adding more features.

This paper proposes a way of doing thought experiments to better understand alliance activities in a dynamic innovation race. The tool we have utilized has long been available in the management field since the pioneering work by Nelson and Winter (1973; 1978). The management field, however, has hardly utilized this type of experiment, except a few such as Carroll and Harrison (1998) and Harrison and Carroll (1991). Recently, with the advent of sciences of complexity (e.g., Kauffman, 1995; Bak, 1996) the simulation method has become an indispensable tool to unravel mysteries of complexity inherent in evolving entities. In particular, Wolfram (1984: 188) insists that "computation is emerging as a major new approach to science, supplementing the long-standing methodologies of theory and experiment." It is primarily because a bare human intuition does not work well with complex, evolving systems. Even when researchers use simple assumptions, their consequences are not necessarily obvious especially in dynamic settings as illustrated in this study (Axelrod, 1997). Unlike the popular belief in the field, strategic alliances do not help firms much in the long run at least in Schumpeterian competition.

Our findings leave a warning to those who consider strategic alliances as a strategic tool for a quick fix. Based on a study of more than 200 alliances, Bleeke and Ernst (1995) note that many managers often deceive themselves when they are caught up in the thrill of the chase in forging an alliance with other firm. Strategic alliances are particularly tempting in catch-up situations, or when a firm wishes to avoid head-to-head competition with its formidable competitor. Bleeke and Ernst warned that the alliances formed with managers' self-deception frequently lead the companies to unplanned divestitures. The simulation experiment in this study provides a systematic explanation for why and how this could happen. Our findings also suggest that small firms exposed to higher hazard rates in an innovative race can benefit from strategic alliances in the short run because the collaborative strategy prolongs their stay in risky businesses. However, as firms become substantially large, they are more likely to lose than gain from cost-sharing R&D alliances in the long run.

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Appendix.

Parameters for Basic Simulation Model

R&D Investment Parameters

Initial Capital (K_{i0}) = 200

Cost of a Development Project (ω) = 10

Unit Capital for R&D Investment Increment (τ) = 100

Parameters for Product Development

Return for each product (r_j) = 100

Degree of Creative Destruction (ρ) = 0.5

Product Life Span (φ) = 5

Success Probability for Introduction of a New Product (p) = 0.03

Allocation Parameters

Standard Deviation for Arbitrary Allocation (σ) = 0.1

Shape parameter for Beta Distribution (α_1) = 0.2

Shape parameter for Beta Distribution (α_2) = 0.8

TABLE 1

Effectiveness of Alliance over Diverse Conditions:

The Results of 100 Simulation Runs

	Survivors		**Average Capital**		
Average Proportion of Loss	Alliance	Non-alliance	Alliance	Non-alliance	Products
0.1	139.9	100.2	2453.67	9042.85	1549.4
0.2	98.1	101.7	1166.89	9100.35	1288.8
0.3	60.8	101.3	586.74	9307.05	1205.5
0.4	28.6	103.1	302.63	9078.23	1157.8
0.5	8.7	105.6	167.77	9157.42	1184.4
0.6	1.2	103.8	66.69	8975.54	1140.9
0.7	0.1	103.6	114.11	8899.25	1124.1
0.8	0.1	105.5	82.93	9052.66	1164.4
0.9	0.1	103.8	204.46	9050.30	1146.5