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Profitability, success probabilities, and incentives for cooperative R&D

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Abstract

As is widely conjectured, duopolists form a cost-sharing cooperative R&D alliance to develop a product - regardless of the probability of research success is either very high or very low. This study establishes that most low probabilities of research success cannot induce a financially successful cooperative R&D alliance. Incorporating the constraints in non-negative expected profits eliminates more than 95% probability of the parameter space where the probability of success is lower than 0.5. Our results further demonstrate that non-negative expected profits are attainable when the monopoly profit is not large in relation to duopoly profits, the fixed cost of R&D investment is low and the demand is large.

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1. Introduction

This study investigates the role of profitability conditions with respect to how probability of success influences cooperative R&D. In an oligopolistic market, the constraint of non-negative (expected) profits is involved in the theoretical models, possibly affecting the equilibrium (e.g., Schmalensee 1976, Demange and Henriet 1991 and Flueta and Garellab 2002). The pioneering work of Marjit (1991) presented a model of cooperative R&D motivated by cost-sharing under uncertainty in which both very high and very low probabilities of success in R&D can induce firms to form a R&D alliance. Marjit *et al.* (2001), Kabiraj and Mukherjee (2000) and Mukherjee and Ray (2009) subsequently applied Marjit's model to merger decisions, patent infringement agreements, and uncertain patent applications.

Empirical studies emphasize the notion of non-negative expected profits. For instance, Brien (2003) distinguished how technically successful and financially successful R&D differ from each other, positing that a R&D project is financially successful if the firm involved makes positive net profits on the project. Marjit (1991) clearly indicated that the constraints of non-negative expected profits are assumed to hold. This article extends the results of that study, with a particular focus on how this constraint affects the role of the probability of success as an incentive to form a cooperative R&D alliance. A situation in which cooperative R&D is financially successful is examined. The analysis is restricted on lower probabilities of success in R&D, which is less than 0.5. This study elucidates how the constraint of non-negative expected profits can affect the relations between probability of success and R&D alliance. Simulation results indicate that avoiding financial failure eliminates 95% of the possibility of cooperative R&D. This finding suggests that the probability of success in most R&D joint ventures with non-negative profits is not "too low," with an average of 0.406 and median of 0.426 in the parameter space where probabilities are equal or lower than 0.5.

2. The Model

This study establishes the model of Marjit (1991) and Combs (1992). Consider a duopolistic market in which each risk-neutral firm invests a fixed cost F in non-cooperative R&D. Duopolistic firms may share the fixed costs equally by engaging in a R&D alliance. Assume that the probability of success of a research project for a firm is p. The probability of success for two firms is independent of each other. The independent assumption rules out the likelihood of a spillover effect. Duopolistic firms compete in the product market. Denote $\pi(2)$ and $\pi(1)$ as each duopolistic firm and monopolistic profits in the product market, with $\pi(1) > \pi(2)$. Also assume that the monopolistic profit is higher than the total profits of duopolistic firms, i.e., $\pi(1) > 2\pi(2)$.

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Next, with the symmetric setting, the net expected profit of each firm without R&D cooperation is calculated as follows:

$$\begin{aligned} \mathrm{E}\Pi_N &= \mathrm{Prob(both\ projects\ succeed)}\pi(2) \\ &\quad +\mathrm{Prob(one\ project\ succeeds\ and\ the\ other\ project\ fails)}\pi(1) - F \\ &= p^2\pi(2) + (1-p)\cdot p\pi(1) - F, \end{aligned}$$

where Prob(both firms succeed)= p^2 represents the likelihood that both research projects of duopolistic firms succeed since the projects for two firms are independent of each other, and $(1-p)\cdot p$ represents the likelihood that only one firm is successful in enjoying the monopolistic profits. The net expected profit for cooperative R&D is as follows:

$$\mathrm{E}\Pi_C = p\pi(2) - F/2$$

Therefore, cooperative R&D is an equilibrium (better than non-cooperative R&D) if $\mathrm{E}\Pi_C - \mathrm{E}\Pi_N \geq 0$, which is true if and only if

$$p(1-p)(\pi(1) - \pi(2)) \leq F/2,$$

or equivalently,

$$p(1-p) \leq 0.5F/(\pi(1) - \pi(2)). \quad (1)$$

From the above inequality, Majit (1991) suggested that very low and very high probabilities of success in R&D induce firms to form a R&D cooperation alliance. This hypothesis is explained by the fact that the incentive for go-alone depends on the other firm's failure (1-p) to multiply its own success p, which becomes the product probability. The constraint of non-negative expected profits is assumed to hold, but is not thoroughly discussed in Marjit (1991). Intuitively, a very low probability is more likely associated with low expected revenues, thus leading to negative expected profits. This study demonstrates how a low probability of success may ensure the constraint of non-negative expected profits.

The constraint of non-negative expected profits for a non-cooperative R&D ($\mathrm{E}\Pi_N \geq 0$) can be rewritten as

$$(1-p)\cdot p \geq (F - p^2\pi(2))/\pi(1), \quad (2)$$

and for the cooperative case ($\mathrm{E}\Pi_C \geq 0$), the non-negative constraints become

$$p \geq 0.5F/\pi(2) \quad (3)$$

This study demonstrates how non-negative conditions of (2) and (3) may affect the condition of a cooperative R&D alliance in (1).

To simplify our notation, let s denote $\pi(2)/\pi(1)$ and t denote $F/\pi(2)$. The above three inequalities are examined by an adequate parameter space. Let $0 < p \leq 0.5$ for a concentration

1 This study adopts the model of Combs (1992), which simplifies the notations with $\pi(1) = \pi_m - \pi$ and $\pi(2) = \hat{\pi}$ in Marjit (1991).

on low probabilities, $0 < s < 0.5$ since $\pi(1) > 2\pi(2)$, and $0 < t < 1$ since $0.5 \geq p \geq 0.5t$. The above three inequalities are thus rewritten as

$$p(1-p) \leq 0.5\, t\, s\, /(1-s), \tag{4}$$

$$(1-p) \cdot p \geq (t - p^2)s, \tag{5}$$

$$p \geq 0.5\, t\ . \tag{6}$$

The above feasible nonlinear conditions in the parameter space $\{(s, t, p)|\ 0 < s < 0.5,\ 0 < t < 1,\ 0 < p \leq 0.5\}$ are examined by separating 240 uniform interval subdivisions for each parameter and, therefore, have 240*240*240= 13,824,000 small cuboids as an acceptable scale to obtain a precise value. In each cuboid, the above three conditions are verified for only the center point with median parameter values. The results are precise to 2 decimal place.[2] Notably, a higher number of intervals do not increase no more than two decimals in terms of the precision for parameters p, s, and t. Also, 3,547,945 cuboids (25.67%) satisfy conditions (1) and (4). This finding suggests that for only 25.67% of the parameter space, cooperative R&D is better than the non-cooperative case.

Among the cuboids satisfying (4), 150,596 cuboids (4.24%) satisfy the non-negative expected profits condition (5) and 305,664 cuboids (8.62%) satisfy condition (6). Only 4.24% (150,596 cuboids) satisfy both (5) and (6). This finding suggests that 95.76% (=100%-4.24%) of the parameter space, i.e., more than more than 95% of the parameter space, in which (4) is satisfied, can be eliminated by the constraints of non-negative expected profits (5) and (6). The financially successful condition plays an explicit role on cooperative R&D when probabilities of success are lower than 0.5.

Table I lists the mean and median values of parameters that satisfy conditions (4)-(6). Panel A suggests that very low probabilities (with a mean of 0.155 and a median of 0.113) are conducive for cooperative R&D if conditions (5) and (6) are disregarded. Panel B reveals that probabilities of success (with a mean of 0.406 and a median of 0.426) are not too low if the constraints of non-negative profits are satisfied. In our illustrations, the fact that probabilities are withdrawn uniformly from the interval (0, 0.5), with mean and median values of 0.25 explains why the mean and median values of probabilities in Panel B are markedly higher than those in Panel A. This finding suggests that most probabilities that induce cooperative R&D with non-negative

[2] The main results have the same precision to 2 decimal places by using 150 intervals for each parameter. An additional number of interval subdivisions substantially increase the number of observations (e.g., 500*500*500=1.25*10^8 cuboids for 500 interval subdivisions) without significant improvements in the precision. Consequently, analysis is difficult owing to limited capacity in most statistic programs.

expected profits are not too low. Panel C provides similar results if only condition (5) is satisfied, i.e., if the R&D alliance provides non-negative expected profits.

Table I. Mean and median values for parameters satisfying (4) in Panel A, (4)-(6) in Panel B and (4) and (6) in Panel C.

Parameter	p	$s\ (=\pi(2)/\pi(1))$	$t\,(=F/\pi(2))$
	Panel A: $\mathrm{E}\Pi_C - \mathrm{E}\Pi_N \geq 0$		
Mean	0.155	0.366	0.687
Median	0.113	0.391	0.724
	Panel B: $\mathrm{E}\Pi_C - \mathrm{E}\Pi_N \geq 0$, $\mathrm{E}\Pi_N \geq 0$ and $\mathrm{E}\Pi_C \geq 0$		
Mean	0.406	0.455	0.632
Median	0.426	0.462	0.637
	Panel C: $\mathrm{E}\Pi_C - \mathrm{E}\Pi_N \geq 0$ and $\mathrm{E}\Pi_C \geq 0$		
Mean	0.405	0.455	0.691
Median	0.426	0.462	0.699

Comparing the mean and median values of $s\ (=\pi(2)/\pi(1))$ and $t\ (=F/\pi(2))$ in Panels A and B reveals that the constraints of non-negative expected profits are more likely to hold when $\pi(2)/\pi(1)$ is relatively large and $F/\pi(2)$ is relatively low. Restated, when the relative advantage of a monopolistic profit in comparison with duopolistic profits is insignificant and when the fixed costs of R&D investment are low, duopolistic firms are more likely to gain non-negative profits.

Interestingly, $s = \pi(2)/\pi(1)$ has a minimum value of 0.253 for all parameters that satisfy the three inequalities.[3] Consider a simple case with linear inverse demand curve $\pi(1) = P = A - bQ$ and a constant unit cost c. Correspondingly, $\pi(1) = (A-c)^2/4b$ and $\pi(2) = (A-2c)^2/9b$, and then,

$$s = \pi(2)/\pi(1) = \frac{4}{9}(A-2c)^2/(A-c)^2 \geq 0.335.$$

The above equation implies that $A > 8.59c$. Namely, if the demand size measured by the intercept of the inverse demand is lower than 8.59 times the unit cost, any low probability lower than 0.5 cannot induce financially successful cooperative R&D.

[3] If we consider only conditions (4) and (5) as in Panel C, the minimum value of s is still 0.335.

3. Conclusion

This study demonstrates that profitability affects the incentive of cost-sharing cooperative R&D when probabilities of success are lower than 0.5. Incorporating the constraints in non-negative expected profits in cost-sharing cooperative R&D reduces more than 95% of the possibilities of the parameter space. The probabilities of success that are less than 0.5 of R&D are generally not adequately to induce duopolistic firms to form R&D joint ventures with the constraints of non-negative expected profits. Simulation results indicate that the non-negative expected profits are more likely to be satisfied when the relative advantage of a monopolistic profit (as compared with duopolistic profits) is insignificant, when the fixed cost of R&D investment is low and the demand size is large. Results of this study provide further insight into how the probability of success and R&D alliance are related.

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