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Abstract

We investigate R&D incentive under patent protection with cooperation option. Chowdhury [Economics Letters, 2005, 89(1), 120-126] claims that patent protection may decrease R&D incentive when the tournament effect (TE) is negative. However, We show that patent protection in the presence of R&D cooperation option always increases R&D incentive. In addition, to increase R&D incentive under patent protection, this cooperation option strictly dominates imitation and may also dominate royalty licensing depending on R&D cost, introduced by Mukherjee [Economics Letters, 2006, 93(2), 196-201].

JEL classification: O32, O34, O38
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1 Introduction

Patent protection has been widely applied as one of the most important policies to encourage R&D incentive and reduce technology free riding (spillover) among competitive firms. However, Chowdhury (2005) shows that patent protection may adversely reduce R&D incentive via the *tournament effect* (TE) if firms simultaneously undertake similar activities of technology innovation. In the same scenario, Mukherjee (2006) claims that the effect from either imitation or royalty licensing under patent protection is likely to dominate TE, which implies that patent protection may still be effective to raise R&D incentive in the presence of imitation or royalty licensing.

Although technology spillover decreases to zero under patent protection, obviously, cooperative R&D as an option can still be undertaken by firms[1]. Rather, because of uncertainty from patenting tournament, it may increase incentive of cooperation in R&D. In this paper, we incorporate cooperation option into patent protection of encouraging R&D incentive, which is not considered in the cases of Chowdhury (2005) and Mukherjee (2006). We show that patent protection always increase R&D incentive in the presence of R&D cooperation option. In addition, to increase R&D incentive under patent protection, cooperative R&D strictly dominates imitation and may also dominate royalty licensing depending on R&D cost.

2 The Setup

A duopoly market consists of two firms, 1 and 2, who produce a homogeneous good. Let q_i be the output of firm $i, i = 1, 2$. The inverse market demand function is $f(q)$, where $q = q_1 + q_2$, and it satisfies $f' < 0$, $f'' < 0$ and $f' + q_i f'' < 0, \forall q, q_i$. Initially, each firm produces with the cost function cq and receives a payoff $\pi(c, c)$, but by investing F on R&D, the cost function can reduce to $c'q$, where $c' \in [0, c]$.

We consider a two-stage game. In stage 1, firms simultaneously decide to whether invest F on R&D or not. In stage 2, they have a Cournot-quantity competition in the market. Under no-patent protection, the firm without investing on R&D can benefit from its rival's technology spillover who invests, thus the marginal cost of the non-innovating firm decreases from c to $\tilde{c}$, where $c' \leq \tilde{c} \leq c$. However,

[1]The possibility of cooperative R&D among firms has also been discussed, such as d'Aspremont and Jacquemin (1988), Suzumura (1992) and Kamien, Muller, and Zang (1992), etc. They show that cooperative R&D but with competition in product market is socially optimal if spillover is sufficiently large. So in this paper, we define cooperative R&D under patent protection as R&D cooperation between firms in stage 1, but product competition in stage 2.

under patent protection, this possibility of technology spillover (free riding) is eliminated. Therefore, the marginal cost of the non-innovating firm remains at c. We solve the subgame perfect Nash equilibrium through backward induction.

Furthermore, without loss of generality, in this paper, we assume that in the situation of cooperative R&D under patent protection, two firms share the cost F equally but both can reduce their marginal cost from c to c'. Hence, the payoff of each firm is $\pi(c', c') - \frac{F}{2}$. Moreover, we know that the following inequality should hold: $\pi(c', c') - \pi(c, c) > \frac{F}{2}$.[2]

In general R&D activities are time taking and need to last for a long period, i.e, pharmaceutical innovations[3]. Therefore, we assume that if one firm chooses R&D cooperation but the other firm chooses to innovate by itself, it is very likely that the firm choosing cooperative R&D realizes its rival's decision, and adds up from the half cost to the entire cost F in order to accomplish the innovation. So in this case, both firms are still in the patent tournament and the expected payoff of each firm is $\frac{\pi_1(c',c)+\pi_1(c,c')}{2} - F$.

Table 1: Payoffs under patent protection with cooperative R&D option

	Cooperative R&D	No R&D
Cooperative R&D	$\pi(c', c') - \frac{F}{2}$, $\pi(c', c') - \frac{F}{2}$	$\pi_1(c', c) - F$, $\pi_2(c', c)$
No R&D	$\pi_1(c, c')$, $\pi_2(c, c') - F$	$\pi(c, c)$, $\pi(c, c)$

Then, from Table (1.), under patent protection with cooperative R&D option, we can obtain the non-strategic incentive (N(C)) and the strategic incentive (S(C)) of firm 1 as follows

$$N(C) = \pi_1(c', c) - \pi(c, c) - F \quad (1)$$

and

$$S(C) = \pi(c', c') - \pi_1(c, c') - \frac{F}{2} \quad (2)$$

3 Cooperative R&D and Patent Protection

In this section, we investigate firms' choices under patent protection with cooperative R&D option. Following Chowdhury (2005), N(NP) and N(P) represent the *non-strategic incentive* of non-patent competition and patent protection; S(NP)

[2]Since under no patent protection, the minimum condition of both firms investing R&D should be such that $\pi(c', c') - \pi(c, c) \geq F$, which implies the inequality in cooperative R&D.

[3]Prentis, Lis, and Walker (1988) show that "average development times increased from less than 2 years between 1964 and 1965, to around 8 years in the 1980s with a consequent reduction in the effective patent life".

and S(P) represent the *strategic incentive* of non-patent competition and patent protection.

The non-strategic incentive for R&D does not change when both firms choose cooperative R&D under patent protection. So we only need to compare strategic incentive of R&D investment between patenting and cooperative R&D:

$$S(P) - S(C) = \left[\frac{\pi_1(c', c) + \pi_1(c, c')}{2} - \pi(c', c')\right] - \frac{F}{2} \tag{3}$$

The first term in the square bracket is the tournament effect. Consequently, we also see that firms choose patenting if and only if $S(P) - S(C) \geq 0$, which indicates that if R&D cooperation is available for firms under patent protection, patenting only generates more strategic incentive for R&D than that of cooperation when $TE \geq \frac{F}{2}$; otherwise, cooperative R&D is preferred under patent protection. Furthermore, when TE < 0, since $S(P) - S(C) < 0$ and $\pi(c', c') - \pi(c, c) > \frac{F}{2}$, the subgame perfect Nash equilibrium is both firms choosing cooperative R&D under patent protection. Thus, we have the following proposition:

Proposition 1. *R&D incentive always increases under patent protection with cooperative R&D option irrespective of the tournament effect. If TE* < 0*, firms choose cooperative R&D under patent protection.*

4 Imitation, Royalty Licensing versus Cooperative R&D

Mukherjee (2006) introduces the effects of *non-infringing imitation* and *royalty licensing* under patent protection to demonstrate that their effects may always dominate the tournament effect and thus raise firms' incentives for R&D investment. In this section, we compare effects of cooperative R&D, imitation and royalty licensing on R&D incentive under patent protection[4]. Our result shows that to increase R&D incentive under patent protection, cooperative R&D strictly dominates imitation and may also dominate royalty licensing depending on F.

[4]Furthermore, we also assume that if one firm chooses cooperative R&D but another firm does not, then both firms are still in the patent tournament with non-infringing imitation and royalty licensing, and payoffs are exactly the same as the ones in Mukherjee (2006).

4.1 Imitation versus Cooperative R&D

Under patent protection with non-infringing imitation, each firm still competes to obtain the patent with probability 1/2 under bilateral R&D. Additionally, the patent loser could invest I around the protected innovation with probability z, where $z \in (0,1)$, and reduce its marginal cost to c'. Therefore, the non-strategic and strategic incentives for R&D of a firm under this system are $N(I) = z\pi_1(c', \tilde{c}) + (1-z)\pi_1(c', c) - \pi(c, c) - F$ and $S(I) = z[\pi(c', c') - \pi_1(\tilde{c}, c')] + \frac{(1-z)}{2}[\pi(c', c) - \pi_1(c, c')] - F + \frac{I}{2}$, respectively.

Then we compare R&D incentive in these two regimes. Obviously, cooperative R&D creates higher non-strategic incentive for firms than that of imitation under patent protection, as follows:

$$N(C) - N(I) = z[\pi_1(c', c) - \pi_1(c', \tilde{c})] > 0 \quad (4)$$

Furthermore, the effect on strategic incentive for R&D investment between cooperative R&D and imitation under patent protection is given by

$$S(C) - S(I) = (1-z)\left[\pi(c', c') - \frac{\pi_1(c', c) + \pi_1(c, c')}{2}\right] + z[\pi_1(\tilde{c}, c') - \pi_1(c, c')] + \frac{F - I}{2} > 0 \quad (5)$$

Mukherjee (2006) shows that R&D investment increases, if imitation is very likely under patent protection. Intuitively, this feasible high possibility to make imitation can be explained as follows: when both firms invest on R&D, the patent loser has already incurred F in innovation research, and then owns sufficient knowledge about the new technology, which leads non-infringing imitation to be easily successful (z is very high but $F > I$). Therefore, if imitation is very likely, i.e., $z \to 1$, Eq(5.) always holds, which indicates that cooperative R&D of firms induces more strategic incentive for R&D than that of imitation under patent protection. Thus, to increase R&D incentive under patent protection, cooperative R&D strictly dominates imitation.

4.2 Royalty Licensing versus Cooperative R&D

Under patent protection with royalty licensing, firms compete in a patent tournament with probability 1/2. The patent holder may sell royalty licensing by charging a royalty of $G(.,.)$ to the non-patent holder, so the patent loser can reduce its marginal cost from c to c'. Consequently, the non-strategic and strategic incentives for R&D of firm 1 under this regime are $N(RL) = \pi_1(c', c) + G(c', c) - \pi(c, c) - F$

and $S(RL) = \frac{\pi_1(c',c)+G(c',c)-\pi_1(c,c')}{2} - F$, respectively.

Obviously, $N(RL) - N(C) > 0$, it shows that royalty licensing creates higher non-strategic incentive for R&D than cooperative R&D under patent protection. However, the effect on strategic incentive for R&D investment between cooperative R&D and royalty licensing under patent protection is given by

$$S(C) - S(RL) = \pi(c', c') - \frac{\pi_1(c', c) + \pi_1(c, c')}{2} - \frac{G(c', c)}{2} + \frac{F}{2} \qquad (6)$$

which depends on F, we have Eq.(6) $\lesseqgtr 0$.[5]

We know that both $N(C)$ and $N(RL)$ are greater than $N(NP)$. Thus, which regime creates higher incentive of R&D investment between cooperative R&D and royalty licensing is ambiguous, which depends the sign of Eq.(6).

Proposition 2. *Cooperative R&D of firms creates higher R&D incentive than that of imitation under patent protection. Moreover, either cooperative R&D or royalty licensing would be preferred, particularly depending on the magnitude of F, even if both regimes under patent protection increase R&D incentive.*[6]

[5]Mukherjee (2006) only shows that the optimal level of royalty implies $[\pi_1(c', c) + G(c', c)] > [2\pi(c', c') - \pi_1(c, c')]$.

[6]Specifically, Che and Yang (2009) also consider the same scenario but patent protection is with fixed-fee licensing. They show that patent protection in the presence of fixed-fee licensing always increases R&D incentive. Furthermore, here we can compare which regime creates higher R&D incentive between cooperative R&D and fixed-fee licensing under patent protection. Following Che and Yang (2009), first, we have that $N(FL) = \pi(c', c') - \pi(c, c) + K(c', c) - F$ and $S(FL) = K(c, c') - F$, where the licenser can offer a contract with fixed-fee licensing $K(.,.)$ after R&D, and the licensee accepts the contract if it is not worse off than no fixed-fee licensing. Since the game is symmetric, the optimal license under patent protection with fixed-fee licensing implies that

$$K(c', c) = \pi(c', c') - \pi_1(c, c') = \pi_1(c', c) - \pi(c', c') \qquad (7)$$

Then we compare R&D incentive in these two regimes. Obviously, cooperative R&D creates the same non-strategic incentive for firms as fixed-fee licensing under patent protection:

$$N(C) - N(FL) = \pi_1(c', c) - \pi(c', c') - K(c', c) = 0, \qquad (8)$$

Furthermore, effect on the strategic incentives for R&D investment between cooperative R&D and fixed-fee licensing under patent protection is given by

$$S(C) - S(FL) = \frac{F}{2} > 0 \qquad (9)$$

which shows that cooperative R&D of firms induces more strategic incentive for R&D than that of fixed-fee licensing under patent protection. Thus, to increase R&D incentive under patent protection, cooperative R&D strictly dominates fixed-fee licensing.

5 Conclusion

In this paper, we show that patent protection with cooperative R&D option is always preferred to increase incentives for and the equilibrium level of R&D, compared to two regimes: non-patent protection, patent protection with imitation; but may also dominate patent protection with royalty licensing, particularly depending on R&D cost.

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