Patent Protection with a Cooperative R&D Option*

XiaoGang Che† Yibai Yang‡

December 2011

Abstract

Patent protection may decrease R&D incentives due to the tournament effect. In this paper, we show that patent protection in the presence of a cooperative R&D option always increases the R&D incentive. In addition, this option dominates imitation to increase the R&D incentive under patent protection, and may also dominate royalty licensing depending on the R&D cost.

JEL classification: O31; O34; O38.

Keywords: Cooperative R&D; Patent protection; R&D incentive

1 Introduction

Patent protection has been widely applied as one of the most important mechanisms for encouraging the R&D incentive and reducing technology free riding (spillover) among competitive firms. However, Roy Chowdhury (2005) shows that patent protection may adversely decrease the R&D incentive via the *tournament effect* (TE) if firms simultaneously undertake similar activities of technology innovation. In the same scenario, Mukherjee (2006)

*We are grateful to an anonymous referee and Arijit Mukherjee for their helpful comments and suggestions.

†Department of Economics, University of Alberta, Edmonton, Alberta, T6G 2H4, Canada. *Email* address: che1@ualberta.ca.

‡Corresponding author. Business School and School of Economics, University of Sydney, Sydney, NSW, 2006, Australia. *Email* address: yyan7045@uni.sydney.edu.au.

claims that the effect of either imitation or royalty licensing under patent protection is likely to dominate TE, and create higher R&D investment.

There is also a large body of literature discussing the possibility of cooperative R&D among firms, such as d'Aspremont and Jacquemin (1988), Kamien, Muller, and Zang (1992), Suzumura (1992), and the following papers. They show that welfare would be improved if firms cooperate in the R&D stage and then compete in product market.

In this paper, we incorporate a *cooperative R&D* option into patent protection for encouraging R&D incentives. We show that patent protection always increases R&D incentives in the presence of a cooperative R&D option. In addition, this option dominates imitation to increase R&D incentives under patent protection, and may also dominate royalty licensing depending on the magnitude of the R&D cost.

2 The Setup

Suppose that a duopoly market consists of two firms, $i = 1, 2$, who produce a homogeneous good. Let q_i be the output of firm i. The inverse market demand function is $f(q)$, where $q = q_1 + q_2$, and it satisfies that $f' < 0$ and $f' + q_i f'' < 0, \forall q,\ q_i$. Initially, each firm produces with the cost function cq and receives the profit $\pi(.,.)$, in which the first (second) argument represents the marginal cost of firm 1 (firm 2). Nevertheless, by investing an amount $F > 0$ in R&D, each firm's cost function changes to $c'q$, where $c' \in [0, c)$.

Let us consider a two-stage game. In stage 1, both firms simultaneously decide whether to invest F in R&D or not. Under no patent protection, the firm who does not invest in R&D benefits from the technology spillover of the rival who invests; the marginal cost of the non-innovating firm decreases from c to $\tilde{c}$, where $c' \leq \tilde{c} \leq c$. Under patent protection, this possibility of technology spillover (free riding) is eliminated; the marginal cost of the non-innovating firm remains at c. In stage 2, two firms have the Cournot competition in the product market. Following Roy Chowdhury (2005), the natural rank in stage 2 of the duopoly profits is given by $\pi_1(c', c) = \pi_2(c, c') > \pi(c', c') > \pi(c, c) > \pi_1(c, c') = \pi_2(c', c)$, and for $\tilde{c} < c$, $\pi_1(c', c) > \pi_1(c', \tilde{c}) = \pi_2(\tilde{c}, c')$ and $\pi_2(c', \tilde{c}) = \pi_1(\tilde{c}, c') > \pi_1(c, c')$.

To ensure that both firms are willing to simultaneously invest in R&D, we assume that

Assumption 1. $\pi(c', c') - \pi(c, c) \geq F$.

In this paper, we refer to cooperative R&D under patent protection as cooperation in stage 1 for R&D investment, but product competition between two firms in stage 2. For simplicity, we assume that if two firms choose cooperative R&D in stage 1, they share the cost F equally, reducing each firm's marginal cost from c to c'. In this case, each firm's payoff is $\pi(c', c') - \frac{F}{2}$.

In general, R&D activities are time-consuming and need to last for a long period, such as with pharmaceutical innovations.[1] We accordingly assume that if one firm chooses to cooperate in R&D, but the other firm chooses to innovate by itself, it is likely that the firm choosing to cooperate in R&D realizes its rival's decision, and adds another half cost to incur the entire cost F in order to accomplish the innovation. So in this case, both firms are still engaged in the patent tournament and each firm's expected payoff is $\frac{\pi_1(c',c)+\pi_1(c,c')}{2} - F$.

Solving the game by backward induction, Table 1 illustrates the firms' payoffs in stage 1 under patent protection in the presence of a cooperative R&D option.

Table 1: Payoffs under patent protection with a 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	$\pi_1(c, c')$, $\pi_2(c, c') - F$	$\pi(c, c)$, $\pi(c, c)$

Following the definitions of the *non-strategic* and *strategic incentives* for R&D investment in Roy Chowdhury (2005), where the non-strategic (strategic) incentive is firm i's payoff from R&D, minus its payoff from not doing R&D when firm j does not invest (invests) in R&D, the non-strategic incentive $N(C)$ and the strategic incentive $S(C)$ of firm 1 under cooperative

[1] Prentis, Lis, and Walker (1988) show that, regarding British pharmaceutical innovations, the "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".

R&D are respectively given by:

$$N(C) = \pi_1(c', c) - \pi(c, c) - F \tag{1}$$

and

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

Given $\pi_1(c', c) > \pi(c', c')$, $\pi_1(c, c') < \pi(c, c)$ and Assumption 1, we have that $N(C) > 0$ and $S(C) > 0$, which implies that both firms cooperatively investing in R&D constitutes an equilibrium.

3 Cooperative R&D and Patent Protection

In this section, we investigate the firms' choice of R&D investment under patent protection with a cooperative R&D option. In Roy Chowdhury (2005), the non-strategic incentive $N(P)$ and strategic incentive $S(P)$ for R&D under only patent protection (or patent competition) are $N(P) = \pi_1(c', c) - \pi(c, c) - F$ and $S(P) = \frac{\pi_1(c',c)+\pi_1(c,c')}{2} - \pi_1(c, c') - F$.

Obviously, the non-strategic incentive for R&D does not change regardless of whether or not a cooperative R&D option is available under patent protection. Next, we only need to compare the strategic incentive for R&D investment between patent protection and cooperative R&D, which is given by:

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

The first term in the square bracket is the tournament effect (TE). Consequently, (3) indicates that two firms should choose the patent tournament if and only if $S(P) - S(C) \geq 0$, or TE $\geq F/2$; otherwise, the cooperative R&D option is preferred under patent protection. Thus, we have the following proposition:

Proposition 1. *The firms' R&D incentive always increases under patent protection with a cooperative R&D option, irrespective of the tournament effect.*

When there is only patent protection, both firms invest in R&D if $S(P) > 0$. However, after giving the presence of R&D cooperation under patent protection, both firms always conduct R&D in the subgame perfect Nash equilibria of the 2-stage game. In summary:

Proposition 2. *(I) If $S(P) \geq S(C) > 0$, there exists an equilibrium where both firms invest in R&D with patent competition; (II) If $S(C) > S(P) > 0$ or $S(C) > 0 \geq S(P)$, there exists an equilibrium where both firms undertake cooperative R&D.*

Further, welfare may be also improved in the equilibrium where both firms undertake cooperative R&D, as the duplication of R&D investment would be avoided, while both firms benefit from the new technology.

4 Cooperative R&D versus Imitation and Royalty Licensing

Mukherjee (2006) introduces *non-infringing imitation* and *royalty licensing* under patent protection, and shows that their effects may always dominate the tournament effect and thus raise the firms' R&D incentive. In this section, we compare the effects of the cooperative R&D option, imitation, and royalty licensing on the R&D incentive under patent protection.

4.1 Cooperative R&D versus Imitation

Under patent protection with non-infringing imitation, two firms still compete to obtain the patent, with a probability of 1/2, by doing bilateral R&D. Additionally, the non-patent holder can invest $I > 0$ around the protected technology with a successful probability of $z \in (0, 1)$, and then obtains a similar technology to reduce its marginal cost from c to c'. For unilateral R&D, imitation reduces the marginal cost of the non-innovating firm from c to $\tilde{c}$. Under this regime, the non-strategic and strategic incentives for the R&D of a firm (e.g. firm 1) 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.

We first compare the non-strategic incentive between cooperative R&D and imitation:

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

Obviously, (4) > 0; cooperative R&D creates a higher non-strategic incentive for R&D investment than imitation. Further, the comparison of strategic incentive gives:

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

Mukherjee (2006) claims that successful imitation is very likely, i.e. $z \to 1$. This is because, after the patent tournament where both firms invested in R&D, the non-patent holder has already incurred F in innovation research. Hence, it possesses a sufficient amount of knowledge about the new technology, leading the non-infringing imitation to be easily achieved. Given that $z \to 1$ and $F > I$, (5) > 0. That is, cooperative R&D induces a higher strategic incentive for R&D investment than imitation. To summarize, the cooperative R&D option strictly dominates imitation for increasing the R&D incentive under patent protection.

4.2 Cooperative R&D versus Royalty Licensing

Under patent protection with royalty licensing, the firms remain competing in a patent tournament with a probability of 1/2. The patent holder (licenser) may sell a license to the non-patent holder (licensee) by charging a royalty of $G(.,.)$, so that the licensee can also reduce its marginal cost from c to c'. In this case, the non-strategic and strategic incentives for the R&D of the patent holder (e.g. firm 1) 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.

It is easy to see that royalty licensing creates a higher non-strategic incentive for R&D investment than cooperative R&D, since $N(RL) - N(C) > 0$. However, the comparison of the strategic incentive becomes ambiguous:

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

where we could have (6) $\lesseqqgtr 0$, depending on the magnitude of F.[2] Thereby, it is possible that either regime induces a higher incentive for R&D investment under patent protection.

Summarizing Section 4 shows:

Proposition 3. *Under patent protection, (I) a cooperative R&D option generates a higher incentive for R&D investment than imitation; (II) either cooperative R&D or royalty licensing would be preferred to increase the R&D incentive, particularly depending on the R&D cost.*[3]

5 Conclusion

This paper shows that patent protection in the presence of a cooperative R&D option always increases the R&D incentive, irrespective of the tournament effect. Further, under patent protection, the cooperative R&D option always generates a higher incentive for R&D investment compared to imitation. However, the dominance of this option becomes unclear when compared with royalty licensing.

Appendix

Proofs for Patent Protection with Licensing

This note illustrates that fixed-fee licensing under patent protection will always create higher R&D incentives than under no patent protection, irrespective of the tournament effect

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

[3]Che and Yang (2009) consider the case of patent protection with fixed-fee licensing. They show that, in the presence of fixed-fee licensing, both non-strategic and strategic R&D incentives are higher under patent protection than under no patent protection. Here, we further compare the R&D incentive of cooperative R&D and fixed-fee licensing under patent protection. Following Che and Yang (2009), the non-strategic and strategic incentives for the R&D of a firm (e.g. firm 1) with fixed-fee licensing are $N(FL) = \pi(c', c') - \pi(c, c) + K(c', c) - F$ and $S(FL) = K(c', c) - F$, where the licenser can offer a licensing contract with a fixed fee $K(.,.)$, and the licensee accepts the contract if it is not worse off than being without fixed-fee licensing. Since the game is symmetric, the optimal license is given by $K(c', c) = \pi(c', c') - \pi_1(c, c') = \pi_1(c', c) - \pi(c', c')$. The comparison of non-strategic and strategic incentives between the regimes shows that $N(C) - N(FL) = \pi_1(c', c) - \pi(c', c') - K(c', c) = 0$ and $S(C) - S(FL) = F/2 > 0$, suggesting that cooperative R&D generates a higher incentive for R&D investment than fixed-fee licensing under patent protection.

(TE). According to Wang (1998), fixed-fee licensing for the patent-holding firm is inferior to royalty licensing when the cost-reducing innovation is non-drastic. This result is also implicitly given by Rockett (1990), who considers both fixed-fee and royalty licensing and concludes that in equilibrium, the fixed-fee is zero and only the output royalty is positive. Mukherjee (2006) has already proven that royalty licensing under patent protection may always induce higher incentives for R&D investment than under no patent protection, irrespective of TE, which is introduced by Roy Chowdhury (2005). In the following, we show that fixed-fee licensing also has a similar role.

First of all, the natural restrictions and symmetry on the duopoly profits specified in Roy Chowdhury (2005) still apply. Fixed-fee licensing has a net profit transferred from the licensee (firm 2) to the licenser (firm 1). The optimal level of fixed fees charged by firm 1 should be the amount that makes firm 2 indifferent between licensing and no licensing. Given that the game is symmetric, we should have

$$G(c', c) = \pi_1(c', c) - \pi(c', c') = \pi(c', c') - \pi_2(c', c). \tag{7}$$

In fact, this equation implies that TE equals zero. If both firms invest in R&D, the net profit transferred from the licensee to the licenser when the license is sold yields firm 1's payoff, as follows:

$$\begin{aligned} &\frac{1}{2}\left[(p(c', c') - c')q_1(c', c') + G(c', c)\right] + \frac{1}{2}\left[(p(c', c') - c')q_1(c', c') - G(c', c)\right] - F \\ =&\frac{1}{2}\pi(c', c') + \frac{1}{2}\pi(c', c') - F = \pi(c', c') - F. \end{aligned} \tag{8}$$

where $p(c', c')$ and $q_1(c', c')$ represent the market price and the quantity produced by firm 1 when the license is sold, respectively. The fixed-fee $G(c', \tilde{c})$ under no patent protection with licensing is calculated using the same logic as (A.1), implying $G(c', \tilde{c}) = \pi(c', c') - \pi_2(c', \tilde{c}) = \pi_1(c', \tilde{c}) - \pi(c', c')$. Consequently, using $G(c', c)$ and $G(c', \tilde{c})$, the game matrices can be written as follows.

In both tables, the strategies of firm 1 and firm 2 are labeled vertically and horizontally.

Table 2: Payoffs under no patent protection with fixed-fee licensing

	R&D	No R&D
R&D	$\pi(c', c') - F,\ \pi(c', c') - F$	$\pi(c', c') + G(c', \tilde{c}) - F,\ \pi_2(c', \tilde{c})$
No R&D	$\pi_1(\tilde{c}, c'),\ \pi(c', c') + G(\tilde{c}, c') - F$	$\pi(c, c),\ \pi(c, c)$

Table 3: Payoffs under patent protection with fixed-fee licensing

	R&D	No R&D
R&D	$\pi(c', c') - F,\ \pi(c', c') - F$	$\pi(c', c') + G(c', c) - F,$ $\pi(c', c') - G(c', c)$
No R&D	$\pi(c', c') - G(c, c'),\ \pi(c', c') + G(c, c') - F$	$\pi(c, c),\ \pi(c, c)$

For every payoff vector, the first and second expressions represent the net equilibrium payoff of firm 1 and firm 2, respectively.

Thus, from Table 2, we know that the non-strategic and strategic incentives for R&D under no patent protection with fixed-fee licensing for each firm are $N(NPL) = \pi(c', c') - \pi(c, c) + G(c', \tilde{c}) - F$ and $S(NPL) = \pi(c', c') - \pi(\tilde{c}, c') - F$. Similarly, Table 3 gives the non-strategic and strategic incentives for R&D under patent protection with fixed-fee licensing for each firm as $N(FL) = \pi(c', c') - \pi(c, c) + G(c', c) - F$ and $S(FL) = G(c', c) - F$. The direct comparison between $S(FL)$ and $S(NPL)$ using the optimal licensing fixed fee yields

$$S(FL) - S(NPL) = \pi_1(\tilde{c}, c') - \pi_1(c, c') > 0. \tag{9}$$

Similarly, the comparison between $N(FL)$ and $N(NPL)$ yields

$$N(FL) - N(NPL) = G(c', c) - G(c', \tilde{c}) = \pi_1(\tilde{c}, c') - \pi_1(c, c') > 0. \tag{10}$$

This result implies that fixed-fee licensing under patent protection also generates higher incentives for R&D investment than under no patent protection, irrespective of TE. This is because TE becomes zero under this regime, and patent protection eliminates the technology spillover from the innovating firm to the non-innovating firm.

References

Che, X., and Y. Yang (2009): "Patent Protection with Licensing," *Manuscript*.

d'Aspremont, C., and A. Jacquemin (1988): "Cooperative and Noncooperative R&D in Duopoly with Spillovers," *American Economic Review*, 78(5), 1133–1137; Erratum: *American Economic Review*, 80(3), (1990), 641–642.

Kamien, M. I., E. Muller, and I. Zang (1992): "Research Joint Ventures and R&D Cartels," *American Economic Review*, 82(5), 1293–306.

Mukherjee, A. (2006): "Patents and R&D with Imitation and Licensing," *Economics Letters*, 93(2), 196–201.

Prentis, R., Y. Lis, and S. Walker (1988): "Pharmaceutical Innovation by the Seven UK-Owned Pharmaceutical Companies (1964-1985)," *British Journal of Clinical Pharmacology*, 25(3), 387–396.

Rockett, K. (1990): "The Quality of Licensed Technology," *International Journal of Industrial Organization*, 8(4), 559–574.

Roy Chowdhury, P. (2005): "Patents and R&D: The Tournament Effect," *Economics Letters*, 89(1), 120–126.

Suzumura, K. (1992): "Cooperative and Noncooperative R&D in an Oligopoly with Spillovers," *American Economic Review*, 82(5), 1307–20.

Wang, X. H. (1998): "Fee versus Royalty Licensing in a Cournot Duopoly Model," *Economics Letters*, 60(1), 55–62.