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Keele Economics Research Papers

KEELE UNIVERSITY

Keele ▪ October 2002

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ISSN 1352-8955

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Licensing and the Incentive for Innovation

by

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Date October 2002

Abstract Previous literature has mostly considered R&D and licensing activities separately. In this paper we examine the effect of licensing on R&D and social welfare. We show that the effect of licensing on the incentive for doing R&D is ambiguous and depends on the costs of doing R&D. We also show that the possibility of licensing can change the identity of the innovating firm. However, we find that social welfare is non-decreasing in presence of licensing.

Keywords Licensing, R&D, Welfare

J.E.L. Class D43, L13, O34

Notes The authors are solely responsible for the views presented here but not the University.

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1 Introduction

Technological progress is one of the key factors for economic development. In business world, each firm takes several actions to increase or at least to maintain their competitive advantage against its competitors. One way to maintain competitiveness is through the improvement of technologies. This provides the firms the incentive for doing R&D. There is already a vast literature on R&D, examining the issues such as the timing of innovation, the strategic choices of R&D organization, the effect of the product market collusion on R&D, government policies towards R&D, etc. As a representative sample one may look at Gallini and Winter (1985), Katz and Shapiro (1985), Katz (1986), d'Aspremont and Jaquemin (1988), Kamien et al. (1992), Reinganum (1989), Order and Willig (1985), Suzumura (1992), Hinloopen (1997) and Kabiraj and Mukherjee (2000).

One interesting feature of the earlier contributions is that most of them have ignored other strategic options of the firms for improving production technologies. In particular, previous works ignored the possibility of licensing ex-post R&D, although licensing plays an important role of knowledge sharing in many markets.[1] Often the existence of tacit knowledge makes licensing as an infeasible option and can justify the previous works. But the previous works are not completely relevant for those industries where licensing is not a difficult option. Hence, one important question is to examine the implications of licensing on R&D and welfare. The purpose of this paper is to explore this issue. Therefore, this paper provides a testable hypothesis, which is to examine the relationship between R&D investments and the degree of tacit knowledge involved in the production technology.

The present paper extends the literature on R&D and licensing following the work of Katz and Shapiro (1985). While in Katz and Shapiro (1985) the innovator and producers are different firms, in our paper same firms do innovation and production. Hence, in our paper the firms take strategic decision on licensing as well as on R&D. Thus, in contrast to Katz and Shapiro (1985), our analysis focuses on the role of licensing when the firms have strategic R&D consideration.

In what follows, in the next section we consider a game of R&D and production by Cournot duopolists, which will be extended in section 3 to incorporate the possibility of licensing ex-post R&D. While Katz and Shapiro (1985) considered the possibility of imperfect knowledge transfer under licensing, we abstract our analysis from this possibility and assume that licensing always creates perfect knowledge transfer. This assumption will help us to show the main message of this paper in the simplest way.

[1] To my best knowledge the exceptions are Gallini (1984), Gallini and Winter (1985) and Katz and Shapiro (1985) and Salant (1984). Unlike the present paper, the first two papers considered licensing in a search-theoretic model of R&D and concluded that licensing is always the equilibrium outcome. While in their paper Katz and Shapiro (1985) has focused on a monopoly innovator who is not taking part in the product market, in our paper we focus on a situation where both firms do R&D and also compete in the product market. Further, unlike the present paper Salant (1984) has considered the transfer of property rights to an innovation from one firm to another, but not simultaneous use of the innovation by both firms.

With a monopoly innovator Katz and Shapiro (1985) concluded that whether the possibility of licensing increases or decreases the incentive for R&D depends on the bargaining power of the licenser. In contrast to this result, our finding shows that for any positive bargaining we have the possibility of higher and lower incentive for R&D in presence of licensing. More specifically, we show that for any positive bargaining power of the licenser there are costs of doing R&D for which we can have higher and lower incentive for R&D. However, for a given cost of doing R&D, the incentive for higher R&D can increase with higher bargaining power of the licenser. Further, there are costs of doing R&D for which the incentive for R&D will not be affected with the presence of licensing.

The reason for our findings is easy to understand. Suppose there is no possibility of licensing ex-post R&D and costs of doing R&D are such that the competing firms always do R&D. In this situation, the possibility of licensing may discourage a firm to do R&D. With a positive bargaining power, the possibility of licensing helps the non-innovating firm to get the advantage of the superior technology as well as to get the benefit by saving the cost of doing R&D. Thus, the possibility of licensing reduces the incentive of a firm for doing R&D when its competitor does R&D.

Now, consider that the costs of doing R&D are such that no firm wants to do R&D without the possibility of licensing ex-post R&D. In this situation, the possibility of licensing helps a firm to raise its profit through technology licensing if its competitor does not do R&D. Thus, the possibility of licensing increases the incentive for doing R&D.

We also show that the possibility of licensing can change the identity of the innovating firm. If the bargaining power of the licenser is low, products are not close substitutes and costs of doing R&D take particular values (Proposition 4(c)) then the possibility of licensing can alter the identity of the innovating firm. Thus, in contrast to Katz and Shapiro (1985), we show that if the bargaining power is not sufficiently large then even if bargaining power increases, the presence of licensing can reduce the incentive for R&D of a firm when costs of doing R&D take certain values and the products are not close substitutes.

Thus, this paper also extends the literature following the work of Gallini (1984) by allowing both firms to engage in licensing as well as looking at the incentive for doing R&D by both firms. Further, unlike Gallini (1984), we consider that both firms start their R&D from symmetric cost of production.

Often governments take various measures to encourage indigenous R&D. Hence, this paper shows that the possibility of licensing can significantly influence the government policies trying to encourage indigenous R&D. Since the possibility of licensing has important implications on R&D, the policies trying to encourage R&D should be careful about these effects. As we will show, in this respect, both cost reduction from R&D and cost of doing R&D become important factors. Further, the possibility of licensing could have an important influence on the cooperative R&D strategies of the firms, as it significantly changes the profits of the competing firms under non-cooperative set up. However, even if the effect of licensing on R&D

investment depends on the cost of doing R&D, we find that social welfare never reduces in presence of licensing.

We have already mentioned that most of the earlier works on R&D have ignored the role of licensing ex-post R&D while analyzing several issues on R&D. The previous papers have mostly concentrated on innovations those are drastic in nature, i.e., if all the firms are not successful in R&D then only the successful innovators produce in the product market. In this paper we find that licensing does not have any influence when the cost reduction from R&D is sufficiently large and products are close substitutes. Thus, like Katz and Shapiro (1985), this paper also justifies the analysis of the earlier papers for close substitutes with drastic R&D, ignoring the possibility of licensing. When cost reduction from R&D is not sufficiently large or the products are not close substitutes, the possibility of licensing may have important influence on the incentive for doing R&D.

Rest of the paper is structured as follows. The next section considers a two-stage game of R&D competition, which gets extended to a three-stage game of R&D competition in section 3. The implication on welfare has been examined in section 4. Section 5 concludes the paper.

2 A dynamic game of R&D and production

Assume that there are two firms, labeled 1 and 2. Each of these firms has a technology corresponding to constant marginal cost of production (MC) c. These firms produce a horizontally differentiated product and compete like Cournot duopolists in the product market. We assume that if a firm does R&D then it needs to invest an amount k. R&D helps a firm to reduce its MC to c_l.[2] In our analysis, for simplicity, we assume that firm 1 takes decision on R&D investment prior to firm 2's decision. The main purpose of considering this sequential move about R&D investment is to eliminate the possibility of mixed strategy equilibrium in our analysis. The subsequent announcements of the firms on their future research strategies might be a justification for this sequential nature of R&D. Alternatively, one might think that firm 1 got the knowledge about the new technology before firm 2. Hence, firm 1 has the ability to commercialize its product before firm 2. With this interpretation we can interpret the term k as the cost for commercializing the basic knowledge. So, while taking its decision on R&D, firm 2 knows whether firm 1 has decided to do R&D or not.[3]

We consider the following demand structure for our analysis. We assume that the representative consumer's utility is a function of consumption $q = (q_1, q_2)$, where q_1 and q_2 are the outputs of firm 1 and firm 2, and the numeraire good m. It is given by $U(q) + m$ with

[2] See, e.g., Bester and Petrakis (1993) for this type of R&D process.

[3] In the following analysis we will mention where the equilibrium could be influenced if we had considered a simultaneous R&D decisions of these firms.

$$U(q) = a(q_1 + q_2) - \frac{1}{2}(q_1^2 + 2\gamma q_1 q_2 + q_2^2), \tag{1}$$

where the term γ shows the degree of product differentiation and can take any value between 0 and 1. If $\gamma = 0$, this implies that the products of these firms are isolated but for $\gamma = 1$, the products of these firms are perfect substitutes. We assume that $a > c$.

The above utility function given in (1) generates the following inverse demand function for the ith firm:

$$P_i = a - q_i - \gamma q_j, \tag{2}$$

where, $i, j = 1,2$, $i \neq j$.

We consider the following game in this section. At stage 1, firm 1 decides whether to invest in R&D or not. Observing firm 1's decision, at stage 2, firm 2 decides whether to do R&D or not. Then, in stage 3, these firms compete in the product market like Cournot duopolists. We solve the game through backward induction. Figure 1 shows the sequence of moves of this game.

Figure 1

In the following analysis we define the profit of the ith firm, $i = 1,2$, in the product market for a particular degree of product differentiation by $\pi_i(.,.;\gamma)$, where the first (second) argument in the profit function stands for the MC of firm 1 (firm 2).

2.1 R&D strategy of firm 2

First, consider the subgame conditional on non-R&D by firm 1. Here, firm 2 will do R&D provided

$$\pi_2(c, c_l; \gamma) - \pi_2(c, c; \gamma) > k. \tag{3}$$

The condition (3) shows firm 2's stand-alone incentive for doing R&D, i.e., the incentive for doing R&D by firm 2 when the firm 1 does not do R&D. If the condition (3) does not satisfy then firm 2 will not do R&D given that firm 1 decided not to do R&D.

Now consider the subgame conditional on R&D by firm 1. Here, firm 2 will do R&D provided

$$\pi_2(c_l, c_l; \gamma) - \pi_2(c_l, c; \gamma) > k. \tag{4}$$

But, if condition (4) does not hold then firm 2 will not do R&D even if firm 1 does R&D. Given the demand and cost specifications, it is easy to check that $\pi_2(c,c_l;\gamma)-\pi_2(c,c;\gamma)>\pi_2(c_l,c_l;\gamma)-\pi_2(c_l,c;\gamma)$ for $\gamma>0$.[4]

The following lemma summarizes the R&D decision of firm 2.

Lemma 1: *(a) If costs of doing R&D are less than* X, *where* $X=\pi_2(c_l,c_l;\gamma)-\pi_2(c_l,c;\gamma)$, *then firm 2 will always do R&D irrespective of the decision of firm 1. (b) If costs of doing R&D are more than* Y, *where* $Y=\pi_2(c,c_l;\gamma)-\pi_2(c,c;\gamma)$, *then firm 2 will never do R&D irrespective of the decision of firm 1. (c) If costs of doing R&D are between* X *and* Y *then firm 2 will do R&D only if firm 1 decides not to do so.*

2.2 R&D strategy of firm 1

Now, we consider the R&D strategy of firm 1. First, consider the decision of firm 1 when the costs of R&D, i.e., k, is less than $\pi_2(c_l,c_l;\gamma)-\pi_2(c_l,c;\gamma)$. Firm 1 realizes that it will earn a profit equal to $\pi_1(c_l,c_l;\gamma)-k$ if it is engaged in R&D, otherwise it will earn a profit equal to $\pi_1(c,c_l;\gamma)$. For these costs of doing R&D, it is better for firm 1 to do R&D compared to non-R&D. In this situation we find that both firms will do R&D and each will receive a net payoff equal to $\pi_1(c_l,c_l;\gamma)-k$ (since, $\pi_1(c_l,c_l;\gamma)=\pi_2(c_l,c_l;\gamma)$).

Next consider the situation, where the costs of doing R&D lies between $\pi_2(c_l,c_l;\gamma)-\pi_2(c_l,c;\gamma)$ and $\pi_2(c,c_l;\gamma)-\pi_2(c,c;\gamma)$. In this situation, firm 2 will do R&D if and only if firm 1 does not do R&D. If firm 1 does R&D then, in this situation, it will earn a net profit equal to $\pi_1(c_l,c;\gamma)-k$ but if it does not do R&D then its net profit will be $\pi_1(c,c_l;\gamma)$. Given the costs of doing R&D, it is clear that firm 1's optimal strategy is to do R&D since here $\pi_1(c_l,c;\gamma)-\pi_1(c,c_l;\gamma)>\pi_1(c_l,c;\gamma)-\pi_1(c,c;\gamma)>k$ and $\pi_1(c_l,c;\gamma)=\pi_2(c,c_l;\gamma)$. Therefore, the net profit of firm 1 and firm 2 will be $\pi_1(c_l,c;\gamma)-k$ and $\pi_2(c_l,c;\gamma)$ respectively.

Now, consider the situation where the costs of R&D are more than $\pi_2(c,c_l;\gamma)-\pi_2(c,c;\gamma)$. Here, firm 2 does not do R&D irrespective of the R&D decision taken by firm 1. Firm 1 earns a net profit $\pi_1(c,c;\gamma)$ if firm 1 does not do R&D but earns a net profit equal to $\pi_1(c_l,c;\gamma)-k$ if it does R&D. For these costs of doing R&D, it is better for firm 1 not to do R&D since $\pi_1(c_l,c;\gamma)-\pi_1(c,c;\gamma)<k$.

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[4] We have $\pi_2(c,c_l;\gamma)-\pi_2(c,c;\gamma)=\dfrac{(a(2-\gamma)-2c_l+\gamma c)^2-(a-c)^2(2-\gamma)^2}{(4-\gamma^2)^2}$ and $\pi_2(c_l,c_l;\gamma)-\pi_2(c_l,c;\gamma)=\dfrac{(a-c_l)^2(2-\gamma)^2-(a(2-\gamma)-2c+\gamma c_l)^2}{(4-\gamma^2)^2}$.

We summarize the above discussion in the following proposition.

Proposition 1: *(a) If costs of doing R&D are less than X then both firms do R&D.*
(b) If costs of doing R&D are more than Y then neither firm does R&D.
(c) If costs of doing R&D is between X and Y then only firm 1 does R&D.

At this point it is worth highlighting the role of the sequential movement of R&D investments. If we considered simultaneous moves in the R&D stage then, if the costs of doing R&D were between X and Y, we could have two pure strategy equilibria, where either only firm 1 or only firm 2 does R&D. This possibility could lead to a coordination problem in the non-cooperative set up and could result in situations corresponding to mixed strategy equilibrium in the R&D stage. The sequential R&D decision of these firms helps us to convey the message of this paper in the simplest way by finding the unique pure strategy equilibrium in the R&D stage.

3 Possibility of licensing ex-post R&D

So far we have considered that the firms compete in the product market after R&D. Proposition 1 shows that there are situations where only firm 1 does R&D. Hence, ex-post R&D there is a technological difference between these firms, which may create the avenue for knowledge sharing through technology licensing ex-post R&D. In other situations, i.e., where neither firm does R&D or both firms do R&D, these firms have same MCs and we consider that there is no possibility of technology licensing.[5]

Now, we consider the following game. Like the previous section, firm 1 decides on R&D in stage 1. Then, in stage 2, firm 2 takes decision on R&D. Then in stage 3 these firms decide on technology licensing, if only one firm has done R&D. In stage 4, these firms compete like Cournot duopolists. We solve the game through backward induction. Figure 2 shows the sequence of moves of this game.

Figure 2

3.1 Possibility of licensing

The licensing stage is characterized as follows. If a technologically superior firm (i.e., the only firm doing R&D and reducing MC) decides to license its technology to the technologically inferior competitor then the licenser charges an up-front fixed-fee and licenses the technology to its competitor (see, e.g. Katz and Shapiro, 1985, Marjit, 1990 and Mukherjee, 2001, 2002).[6] However, the licenser and the licensee determine the

[5] Even if two firms produce with same MCs, they can be engaged in technology licensing when these firms have advantages in some parts of these technologies. However, in this analysis we rule out this possibility.
[6] The ability of the licensee to imitate or 'invent around' the technology of the licenser after getting the licensed technology or the lack of information about the licensee's output necessary to make an output royalty contract can restrict the licenser to offer a fixed fee licensing contract.

fixed fee through a generalized Nash-bargaining process.[7] Without loss of generality consider the problem of firm 1 as a licenser. We could have a similar problem for firm 2 also. Hence, if only firm 1 does R&D and wants to license its technology to firm 2, the following maximization problem determines the fee, F, for the licensed technology:

$$\underset{F}{Max}\left(\pi_1(c_l,c_l;\gamma)+F-\pi_1(c_l,c;\gamma)\right)^{\alpha}\left(\pi_2(c_l,c_l;\gamma)-F-\pi_2(c_l,c;\gamma)\right)^{(1-\alpha)}, \tag{5}$$

where $\alpha\in[0,1]$ shows the bargaining power of the licenser and $\pi_1(c_l,c;\gamma)$ and $\pi_2(c_l,c;\gamma)$ are the payoffs of firm 1 and firm 2 respectively if firm 1 does not license its technology to firm 2. Since, firm 1 licenses its technology against a fixed fee, both firms produce with MC c_l under licensing.

Maximization of (5) gives us the optimal licensing fee as

$$F^* = \alpha(2\pi_1(c_l,c_l;\gamma)-\pi_1(c_l,c;\gamma)-\pi_2(c_l,c;\gamma))+(\pi_1(c_l,c;\gamma)-\pi_1(c_l,c_l;\gamma)). \tag{6}$$

Therefore, if firm 1 licenses its technology to firm 2 then the payoff of firm 1 is

$$\pi_1(c_l,c_l;\gamma)-\pi_1(c_l,c;\gamma)+F^* = \alpha(2\pi_1(c_l,c_l;\gamma)-\pi_1(c_l,c;\gamma)-\pi_2(c_l,c;\gamma)) \tag{7}$$

and the payoff of firm 2 is

$$\pi_2(c_l,c_l;\gamma)-\pi_2(c_l,c;\gamma)-F^* = (1-\alpha)(2\pi_1(c_l,c_l;\gamma)-\pi_1(c_l,c;\gamma)-\pi_2(c_l,c;\gamma)), \tag{8}$$

since $\pi_1(c_l,c_l;\gamma)=\pi_2(c_l,c_l;\gamma)$. However, the firms will opt for licensing when neither firm is worse-off under licensing compared to no-licensing, i.e., when the expressions (7) and (8) would be non-negative. The expressions (7) and (8) show that licensing is profitable to these firms provided

$$2\pi_1(c_l,c_l;\gamma) > \pi_1(c_l,c;\gamma)+\pi_2(c_l,c;\gamma). \tag{9}$$

One could find a condition similar to (9) in Mukhopadhyay et al. (1999) where they considered licensing when the licenser had the full bargaining power. Our analysis shows that even if the licenser does not have the full bargaining power, the condition for profitable licensing remains same. The role of the bargaining power is to divide the surplus generated from licensing between the licenser and the licensee. Hence, it is very much intuitive that bargaining power will not affect the condition for profitable licensing but will affect only the amount of surplus going to the licenser and to the licensee.

[7] Throughout the paper we assume that the bargaining power of the licenser and licensee do not depend on the identity of a firm, i.e., whether it is firm 1 or firm 2.

If $\gamma = 0$ then we find that (9) holds always but we find that, given the demand and cost specifications, (9) holds for $\gamma = 1$ provided $c_l > \frac{(5c-2a)}{3}$. Following Mukhopadhyay et al. (1999), we can say that licensing is always profitable for sufficiently differentiated products, i.e., for $\gamma < \hat{\gamma}$. For $\gamma > \hat{\gamma}$ and given the degree of product differentiation, licensing is profitable provided the cost reduction from R&D is not sufficiently large, i.e., $c_l > \hat{c}_l(\gamma)$. The following proposition shows the conditions for profitable licensing. Since the proof of the following proposition is similar to Mukhopadhyay et al. (1999), we are omitting the proof here.

Proposition 2: *(a) If products are sufficiently differentiated, i.e., $\gamma < \hat{\gamma}$, then licensing is always profitable. (b) If products are not sufficiently differentiated then technology licensing is profitable provided the cost reduction from R&D is not sufficiently large, i.e., $c_l > \hat{c}_l(\gamma)$.*

In the following analysis we will assume that the relationship between c and c_l are such that condition (9) holds. Otherwise, licensing will not occur and the analysis of section 2 would be unaffected even if we consider the possibility of licensing ex-post R&D. The earlier works on R&D mainly considered 'drastic' innovations and did not consider the possibility of licensing ex-post R&D. Our findings show that the possibility of licensing would not affect the results of the previous works ignoring the possibility of licensing when the products are close substitutes and cost reduction from R&D is sufficiently large since licensing will not occur in this situation. But, it is important to consider the possibility of licensing when either the cost reduction from R&D is not sufficiently large or the products are not close substitutes.

3.2 R&D strategy of firm 2 with licensing

First, consider the subgame conditional on non-R&D by firm 1. Here, firm 2 will do R&D provided

$$\pi_2(c_l, c_l; \gamma) - \pi_2(c, c; \gamma) + F^* > k \,. \tag{10}$$

Next, consider the subgame conditional on R&D by firm 1. Here, firm 2 will do R&D provided

$$F^* > k \,. \tag{11}$$

From (10) and (11), it is clear that condition (10) may hold even if condition (11) does not hold. In this situation, firm 2 will not do R&D if firm 1 does R&D.

R&D decision of firm 2 is summarized in the following lemma.

Lemma 2: *(a) If $k < F^*$ then firm 2 does R&D irrespective of the R&D decision of firm 1. (b) If $k > Z + F^*$, where $Z = \pi_2(c_l, c_l; \gamma) - \pi_2(c, c; \gamma)$, then firm 2 does not do R&D irrespective of the R&D decision of the firm 1. (c) Suppose $k \in (F^*, Z + F^*)$. Then firm 2 does R&D if firm 1 does not do R&D.*

3.3 R&D strategy of firm 1 with licensing

Now, we look at the R&D decision of firm 1. First, consider the situation where the costs of doing R&D are very small, i.e., $k < F^*$. Here, firm 2 will do R&D irrespective of the R&D decision of firm 1. Net profit of the firm 1 from R&D and non-R&D will be $\pi_1(c_l, c_l; \gamma) - k$ and $\pi_1(c_l, c_l; \gamma) - F^*$ respectively. Therefore, for these costs of doing R&D, firm 1 will do R&D since $k < F^*$.

If we consider the costs of doing R&D to be $k > Z + F^*$, firm 2 will never do R&D. The net profit of firm 1 from R&D and non-R&D will be $\pi_1(c_l, c_l; \gamma) + F^* - k$ and $\pi_1(c, c; \gamma)$. In this situation, firm 1 too will not do R&D since, $\pi_1(c_l, c_l; \gamma) - \pi_1(c, c; \gamma) + F^* = Z + F^* < k$.

Now, we look at the costs of doing R&D such that $k \in (F^*, Z + F^*)$. In this situation, firm 2 will not do R&D if firm 1 does R&D. The net profit of firm 1 from R&D and non-R&D will be $\pi_1(c_l, c_l; \gamma) + F^* - k$ and $\pi_1(c_l, c_l; \gamma) - F^*$ respectively. Firm 1 will do R&D provided $2F^* > k$. We see that $2F^* > k$ for $k = F^*$. But, for $k = Z + F^*$, $2F^* > k$ will be satisfied if the following condition holds:

$$\alpha[2\pi_1(c_l, c_l; \gamma) - \pi_1(c_l, c; \gamma) - \pi_1(c, c_l; \gamma)] > [2\pi_1(c_l, c_l; \gamma) - \pi_1(c_l, c; \gamma) - \pi_1(c, c; \gamma)]. \quad (12)$$

The condition for profitable licensing implies that the term $(2\pi_1(c_l c_l; \gamma) - \pi_1(c_l, c; \gamma) - \pi_1(c, c_l; \gamma))$ is positive. We find that the left hand side (LHS) of (12) is greater than the right hand side (RHS) for $\alpha = 1$. Given the demand and cost specifications, RHS of (12), however, is negative at $\gamma = 1$ but positive at $\gamma = 0$. Further, RHS is continuous in γ over the range $[0,1]$. This implies that RHS of (12) is positive provided the products are sufficiently differentiated, i.e., when γ is lower than a critical level, say γ^*. If $\gamma > \gamma^*$, LHS of (12) is greater than the RHS of (12) for any $\alpha > 0$ since, for these values of γ the RHS of (12) is negative. For $\gamma < \gamma^*$, the LHS of (12) is greater than the RHS of (12) provided the bargaining power of the licenser is sufficiently high, i.e., if α is greater than a critical value, say α^*. For $\alpha < \alpha^*$, LHS of (12) is less than the RHS of (12) when $\gamma < \gamma^*$. Therefore, we find that $2F^* < k$ at $k = Z + F^*$ provided $\gamma < \gamma^*$ and $\alpha < \alpha^*$. Also, the net profit of firm 1 under R&D is continuous in k over $k \in [F^*, Z + F^*]$.

Thus, we can conclude that if $\gamma > \gamma^*$ or $\alpha > \alpha^*$ then firm 1 will do R&D for $k \in (F^*, Z + F^*)$. For $\gamma < \gamma^*$ and $\alpha < \alpha^*$, firm 1 will not do R&D when the costs of doing R&D are greater than a critical level, say k^*. But, for $\gamma < \gamma^*$ and $\alpha < \alpha^*$, firm 1 will do R&D if $k \in (F^*, k^*)$.

The following proposition shows the equilibrium of this game when the firms have the option for licensing ex-post R&D.

Proposition 3: *(a) If costs of doing R&D are such that* $k < F^*$ *then both firms do R&D.*
(b) If costs of doing R&D are such that $k > Z + F^*$ *then neither of these firms do R&D.*
(c) Assume that the costs of doing R&D are such that $k \in (F^*, Z + F^*)$.[8]
(i) Only firm 1 does R&D if either the bargaining power of the licenser is sufficiently high or the products are not sufficiently differentiated, i.e., either $\alpha \geq \alpha^*$ *or* $\gamma \geq \gamma^*$.
(ii) If products are sufficiently differentiated and the bargaining power of the licenser is not sufficiently large, i.e., $\gamma < \gamma^*$ *and* $\alpha < \alpha^*$, *only firm 1 will do R&D for* $k \in (F^*, k^*)$ *and only firm 2 will do R&D for* $k \in (k^*, Z + F^*)$.

The Propositions 2 and 3 show the optimal decision of these firms on R&D. Also, note that for any $\alpha \in (0,1)$, $F^* < X$ and $Y < Z + F^*$. We immediately find the following proposition, which shows the effect of licensing on R&D.

Proposition 4: *(a) If costs of doing R&D are moderate but relatively small, i.e.,* $k \in (F^*, X)$, *then only one firm does R&D with the possibility of licensing but both firms do R&D in the absence of licensing.*
(b) If costs of doing R&D are moderate but relatively large, i.e., $k \in (Y, Z + F^*)$, *then only one firm does R&D in presence of licensing but neither firm does R&D in the absence of licensing.*
(c) In absence of licensing, if only one firm does R&D then it is firm 1 who does R&D. In presence of licensing, if only one firm does R&D then it is firm 1 provided we have one of these three conditions: (i) $\alpha \geq \alpha^*$, *(ii)* $\gamma \geq \gamma^*$ *and (iii)* $k \in (F^*, k^*)$. *But, when all these conditions are violated, then it is firm 2 who will do R&D only.*

Figure 3 summarizes the decisions on R&D in absence of licensing, which is shown in the upper part of the line as NL, and in presence of licensing, which is shown in the lower part of the line as L. R (NR) implies investment (non-investment) in R&D and the terms show R&D decisions of firm 1 and firm 2 respectively.

---

[8] Like section 2, we could have a similar coordination problem for these costs of doing R&D if we have considered simultaneous R&D decisions of these firms. However, the sequential R&D decisions provide the unique pure strategy equilibrium in the R&D stage.

Figure 3

Proposition 4 shows that whether the possibility of licensing increases or decreases the incentive for doing R&D depends on the costs associated with R&D. If the costs of doing R&D are moderate but sufficiently small (Proposition 4(a)) then the possibility of licensing reduces the incentive for doing R&D. Here, the costs of doing R&D are such that each firm wants to do R&D without the possibility of licensing. But, if there is a possibility of licensing ex-post R&D, the positive bargaining power of firm 2 helps it to increase its profit by making a licensing agreement with firm 1. Since the costs of doing R&D are moderate, this licensing agreement helps firm 2 to benefit from saving the costs of doing R&D. Thus, the possibility of licensing after R&D reduces firm 2's incentive for doing R&D when firm 1 does R&D.

If costs of doing R&D are sufficiently high (Proposition 4(b)), the possibility of licensing increases the incentive for doing R&D. Here neither firm does R&D without the possibility of licensing. The possibility of licensing helps firm 1 to increase its payoff through licensing since firm 2 will not do R&D at this cost. In this situation, the gain from licensing increases firm 1's incentive for doing R&D when firm 2 does not do R&D.

In Proposition 4(c) we see that the possibility of licensing changes the identity of the innovating firm. In absence of licensing only firm 1 will do R&D whenever only one firm does R&D. But, in presence of licensing, it is possible that only firm 2 does R&D whenever only one firm does R&D. If the products are sufficiently differentiated (i.e., $\gamma < \gamma^*$) and the bargaining power of the licenser is sufficiently low (i.e., $\alpha < \alpha^*$) then it reduces firm 1's benefit from licensing. Further, when the costs of R&D are not sufficiently low (i.e., for $k \in (k^*, Z + F^*)$), this benefit from licensing will be lower than the benefit from cost saving in R&D and getting the license from firm 2. We have seen that, for these costs of doing R&D, firm 2 will do R&D and license the technology to firm 1 if firm 1 does not do R&D. This possibility helps the firm 1 to get the advantage of the innovated technology in the product market even if firm 1 does not do R&D. Altogether firm 1 will not do R&D and firm 2 will do R&D when $\gamma < \gamma^*$, $\alpha < \alpha^*$ and $k \in (k^*, Z + F^*)$.

4 Effects on welfare

In the previous section we have seen that the effects of licensing on the incentive for doing R&D. In this section we will see how social welfare, which is the summation of consumer surplus and industry profit, will be affected by the possibility of licensing.[9] In this section we will consider only those parametric configurations for which licensing is profitable, when licensing ex-post R&D is a feasible option to these firms.

[9] Here the implicit assumption is that these firms are from the same country and sell their products to the homw market. Hence, social welfare consists of consumer surplus and industry profit.

From the above analysis we find that irrespective of the possibility of licensing both firms will do R&D and neither firm will do R&D if the costs of doing R&D are less than F^* or greater than $Z+F^*$ respectively. Further, only one firm does R&D when the costs of doing R&D are between X and Y. Hence, social welfare will be same with and without licensing, for these costs of doing R&D.

The possibility of licensing significantly affects the incentive for doing R&D when the costs of doing R&D are between F^* and X and between Y and $Z+F^*$.

Let us first consider the situation where the costs of doing R&D are between F^* and X. Here, both firms will do R&D without the possibility of licensing. But, for these costs of doing R&D, only firm 1 will do R&D with the possibility of licensing. The possibility of licensing reduces the total costs of doing R&D but allows both firms to produce using superior technology. Hence, the possibility of licensing raises social welfare when the costs of doing R&D are between F^* and X.

Next, consider the situation where the costs of doing R&D are between Y and $Z+F^*$. Here, neither firm does R&D in absence of licensing. But one of these firms does R&D in presence of licensing.

If there is no possibility of licensing then, given the utility function in (1), social welfare will be

$$W^{nl} = \frac{(a-c)^2(3+\gamma)}{(2+\gamma)^2}. \tag{13}$$

If there is a possibility of R&D then only one firm will do R&D and license the technology to the other firm. Given the utility function in (1), social welfare will be

$$W^{l} = \frac{(a-c_l)^2(3+\gamma)}{(2+\gamma)^2} - k. \tag{14}$$

Expression (14) is negatively related to k. Further, expression (14) is negatively related to α since the upper bound of k is given by $Z+F^*$, which is positively related to α. Hence, (14) reaches the minimal value when $k=Z+F^*$ and α =1.

We find that the expression $(W^{nl}-W^{l})$ reduces to the following expression when $k=Z+F^*$ and α =1:

$$W^{nl}-W^{l} = \frac{(2+\gamma)((a-c)^2-(a-c_l)^2)+(a-c_l)^2}{(2+\gamma)^2} - \frac{(a(2-\gamma)-2c+\gamma c_l)^2}{(4-\gamma^2)^2}. \tag{15}$$

After rearranging, we find that the expression (15) will be positive or negative provided

$$(2+\gamma)(a-c)^2 \underset{<}{\geq} (1+\gamma)(a-c_l)^2 + \frac{(a(2-\gamma)-2c+\gamma c_l)^2}{(2-\gamma)^2}. \tag{16}$$

Left hand side (LHS) of (16) is equal to right hand side (RHS) of (16) at $c = c_l$. Both LHS and RHS of (16) fall with c but the absolute slope of LHS with respect to c is greater than the absolute slope of RHS with respect to c for all $\gamma \in [0,1]$. Hence, we find that expression (15) is negative always.

The following proposition summarizes the above discussion.

Proposition 5: S*ocial welfare is non-decreasing in presence of licensing ex-post R&D.*

5 Conclusion

The literature on R&D generally abstracted the other possible strategic options of the innovating firms. In this paper we examine how the incentive for R&D and social welfare will be affected when the firms have the option for licensing ex-post R&D. Hence, the results of this paper can be used to compare the incentive for R&D in the industries with and without tacit knowledge. While the existence of tacit knowledge makes licensing difficult, the absence of tacit knowledge makes licensing as a feasible option.

We have shown that whether licensing increases the incentive for R&D depends on the costs of doing R&D. Incentive for R&D will be influenced by the presence of licensing if costs of doing R&D are neither sufficiently small nor sufficiently large. If costs of doing R&D are moderate but relatively small then we find that the possibility of licensing reduces the incentive for doing R&D. But, if costs of doing R&D are moderate but relatively large then the possibility of licensing increases the incentive for R&D. For moderate costs of doing R&D, the presence of licensing can also change the identity of the innovating firm. Thus, our results show that the possibility of licensing may have important implications on the government policies or on arrangements for cooperative R&D. However, we find that social welfare never decreases with the possibility of licensing.

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Figures

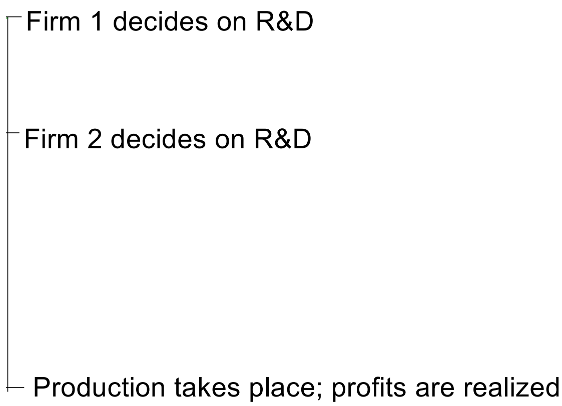

Figure 1: Sequence of moves without licensing

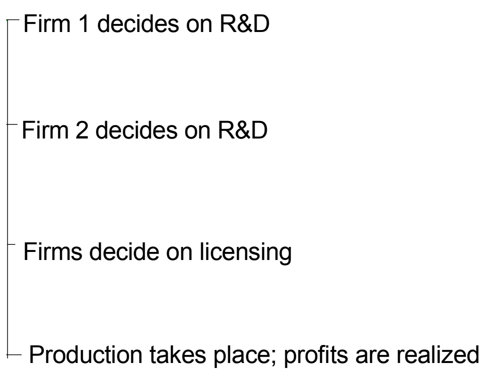

Figure 2: Sequence of moves with licensing

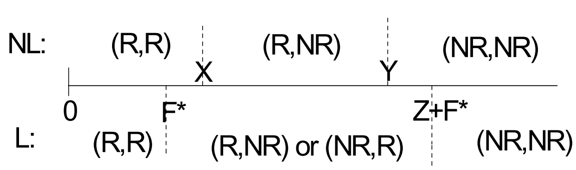

Figure 3: Decisions on R&D investment

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ISSN 1352-8955

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