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'Technology transfer in a Stackelberg structure: licensing contracts and welfare' – Corrigendum*

Short running title: Technology transfer in Stackelberg

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‘Technology transfer in a Stackelberg structure: licensing contracts and welfare’ – Corrigendum

Abstract: This corrigendum seeks to correct the mistake in Kabiraj (2005, The Manchester School) in calculation of the optimal royalty rate when leader is the patent holder, hence it modifies, accordingly, the statements of some propositions.

1. Introduction

In a paper published few years back, Kabiraj (2005, The Manchester School) has discussed technology licensing and its welfare implications to different groups in a Stackelberg structure. Some of the important issues discussed in the paper are the following. Given the size of the innovation and that the patent of a superior technology is owned either by leader or by follower, which licensing contract, fee or royalty, is optimal from the viewpoint of the patentee? Which licensing contract does generate larger consumer surplus and social welfare? Whose innovation, leader’s or follower’s, is more valuable to the consumers and society as a whole? Which firm, leader or follower, has a larger incentive for innovation? Can an appropriate licensing policy induce the desired firm to win the patent race? Hence, which licensing contract be allowed to the innovator is an important question from the perspective of welfare analysis.

Unfortunately, the paper has inadvertently made a mistake in solving the optimal royalty rate under royalty licensing when leader is the innovator. The paper has constructed a three-stage game when in the first stage the patentee leader decides on a royalty rate per unit of output produced by the licensee (follower). Then in the second stage, given the royalty rate, leader decides the quantity to be produced, and in the final stage, taking the royalty rate and leader's output as fixed, follower decides its production. The game is solved by backwards induction. As we shall see below, Kabiraj (2005) has wrongly specified the second stage problem.

Given the royalty rate (r) in the first stage and follower (firm 2) solves its quantity in the third stage, firm 2's output becomes a function of royalty rate and leader's (firm 1's) output (q_1) determined in the second stage. Leader's second stage problem is to maximize, w.r.t. q_1, the sum of its market operated profit $\pi_1^R(q_1, r)$ and royalty income $rq_2(q_1, r)$. The second stage solution will give $q_1 = q_1^R(r)$ and hence $q_2 = q_2(q_1(r), r) = q_2^R(r)$. Hence at the first stage patentee leader's problem is: $\max_r \pi_1^R(r) + rq_2^R(r)$ subject to the relevant restrictions on r. As it is now discovered, Kabiraj (2005) has inadvertently solved the second stage leader's problem as $\max_{q_1} \pi_1^R(q_1, r)$,[1] instead of the problem: $\max_{q_1^R} \pi_1^R(q_1, r) + rq_2(q_1, r)$.[2]

Obviously, with this mistake in specification of the second stage objective function, the optimal royalty solution in Kabiraj (2005) is incorrect. As a result, statements of some results in Kabiraj (2005), which are related to royalty licensing by leader, becomes incorrect. Hence the purpose of this corrigendum is first to recalculate the optimal

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[1] Kabiraj (2005) solution (hence the related results) could perhaps be retained or restored if it would be assumed that the production decisions at the production stage had been taken by the production managers who are concerned about maximizing the profit of the respective production division only, although the firm (patentee) is concerned about maximizing the overall profit of the firm (including the royalty income). This is not all unrealistic. In a corporate type production organization, managers of different divisions of the firm are more concerned about the respective division performance, but the firm is concerned about the overall performance.

[2] Note that when follower is the patentee, although it is a three stage game, the similar problem does not arise.

royalty rate when leader is the patent holder, and then rewrite or revise all the related propositions. In particular, we have corrected and modified the statements of Lemma 2, Proposition 1, 3, 5(b) and (6). As we see, with these corrections some qualitative results have also undergone a change. We follow the notations as used in Kabiraj (2005).

2. Modified Results

Consider optimal royalty licensing contract when leader holds the patent of the innovation. We have already mentioned that this is a three-stage game problem and is solved by backwards induction.

For any royalty r $(0 \leq r \leq \varepsilon)$ per unit of licensee's output and any given leader's output q_1, the follower's third stage problem is:

$$\max_{q_2}(P(q_1+q_2)-(c-\varepsilon+r))q_2 \equiv \pi_2^R((q_1,q_2,r)$$

where $P(q_1+q_{2)}=a-(q_1+q_2)$. This solves q_2 as

$$q_2=\frac{a-c+\varepsilon-r-q_1}{2}\equiv q_2(q_1,r).$$

Then leader's problem in the second stage is

$$\max_{q_1}[P\big(q_1+q_2(q_1,r)\big)-(c-\varepsilon)]q_1+rq_2(q_1,r)\equiv \pi_1^R(q_1,r)+rq_2(q_1,r)$$

This solves for q_1, and the corresponding output and profit expressions of the firms are[3]

$$q_1^R=\frac{a-c+\varepsilon}{2}, \qquad q_2^R=\frac{a-c+\varepsilon-2r}{4},$$

$$\pi_1^R=\frac{(a-c+\varepsilon)(a-c+\varepsilon+2r)}{8}, \qquad \pi_2^R=\frac{(a-c+\varepsilon-2r)^2}{16}$$

Obviously,

[3] These are different from those in Section A1 in Kabiraj (2005), implying the optimal royalty and other results would be different from Kabiraj (2005).

$$q_2^R \geq 0 \qquad \text{iff } \ r \leq \frac{a-c+\varepsilon}{2}.$$

Then the licensor's first stage problem is

$$\max_r \pi_1^R + r q_2^R \qquad \text{subject to } \ r \leq \varepsilon \ \text{ and } \ r \leq \frac{a-c+\varepsilon}{2}$$

The solution to the unconstrained optimization problem is

$$\hat{r} = \frac{a-c+\varepsilon}{2}$$

Note that $\hat{r} \leq \varepsilon$ if and only if $\varepsilon \geq a - c$. Hence, the optimal solution to the problem is

$$r^* = \varepsilon \qquad \text{if } \ \varepsilon < a - c$$

$$r^* = \frac{a-c+\varepsilon}{2} \qquad \text{if } \ \varepsilon \geq a - c$$

The corresponding equilibrium quantities are

$$q_1^R = \frac{a-c+\varepsilon}{2}, \qquad q_2^R = \frac{a-c-\varepsilon}{4} \qquad \text{if } \ \varepsilon < a - c$$

$$q_1^R = \frac{a-c+\varepsilon}{2}, \qquad q_2^R = 0 \qquad \text{if } \ \varepsilon \geq a - c$$

and the payoffs from market operation are

$$\pi_1^R = \frac{(a-c+\varepsilon)(a-c+3\varepsilon)}{8}, \qquad \pi_2^R = \frac{(a-c-\varepsilon)^2}{16} \qquad \text{if } \ \varepsilon < a - c$$

$$\pi_1^R = \frac{(a-c+\varepsilon)^2}{4}, \qquad \pi_2^R = 0 \qquad \text{if } \ \varepsilon \geq a - c$$

Therefore, frim 1's total profit under the royalty contract is

$$\Pi_1^R = \frac{(a-c+\varepsilon)(a-c+3\varepsilon)}{8} + \frac{\varepsilon(a-c-\varepsilon)}{4} \qquad \text{if } \ \varepsilon < a - c$$

$$= \frac{(a-c+\varepsilon)^2}{4} \qquad \text{if } \ \varepsilon \geq a - c$$

Now given the expression of π_1^N (firm 1'a profit under no licensing) in Kabiraj (2005, p. 6), comparing Π_1^R and π_1^N we shall get

$$\Pi_1^R > \pi_1^N \qquad \text{if } \ \varepsilon < a - c$$

$$\Pi_1^R = \pi_1^N \qquad \text{if } \ \varepsilon \geq a - c$$

This leads to the following revised Lemma 2.

(Revised) Lemma 2: When leader holds the patent of the new technology, a royalty licensing strictly dominates no licensing if and only if the innovation is non-drastic (i.e., $\varepsilon < a - c$*).*

Note that with the corrected royalty rate the interval for royalty licensing is extended to $0 < \varepsilon < a - c$ in the upper portion of Fig 1 in Kabiraj (2005, p. 10).

Then to the question of optimal licensing strategy of the leader-cum-innovator we compare Π_1^R and Π_1^F (firm 1's total payoff under the fixed-fee licensing) where Π_1^F is given in Kabiraj (2005, p. 8). We have the following result:

$$\Pi_1^R > \Pi_1^F > \pi_1^N \qquad \text{for } \varepsilon < \frac{2(a-c)}{9}$$

$$\Pi_1^R > \pi_1^N > \Pi_1^F \qquad \text{for } \frac{2(a-c)}{9} \leq \varepsilon < a - c$$

$$\Pi_1^R = \pi_1^N \qquad \text{for } \varepsilon \geq a - c$$

Hence, Proposition 1(a) of Kabiraj (2005, p. 10) should be rewritten correctly as follows.

(Revised) Proposition 1(a): When both fee licensing and royalty licensing are available, royalty licensing dominates fee licensing for all $\varepsilon < a - c$*.*

When leader is the innovator, in equilibrium the industry output is

$$Q_1 = Q_R = \frac{3(a-c)+\varepsilon}{4} \qquad \text{if } \varepsilon < a - c$$

$$= \frac{a-c+\varepsilon}{2} \qquad \text{if } \varepsilon \geq a - c$$

and the industry profit is

$$\begin{aligned}\Pi_1 &= \Pi_R = \Pi_1^R + \pi_2^R = \frac{3(a-c)^2+3\varepsilon^2+10\varepsilon(a-c)}{16} && \text{if } \varepsilon < a-c \\ &= \Pi_N = \pi_1^N + \pi_2^N = \frac{(a-c+\varepsilon)^2}{4} && \text{if } \varepsilon \geq a-c\end{aligned} \tag{2}$$

When follower is the innovator, the corresponding industry output and profit are Q_2 and Π_2, respectively, which are the same as derived in Kabiraj (2005, pp. 14-15). Then comparing the two cases, that is, when leader innovates and when follower innovates, we have:

$$Q_1 = Q_2, \quad \Pi_1 = \Pi_2, \quad \text{therefore,} \ W_1 = W_2$$

where W_i is the overall welfare in equilibrium when firm i is the innovator ($i = 1{,}2$). Therefore, Proposition 3 should be corrected as follows.

(Revised) Proposition 3: When both royalty and fee contracts are available, the industry profit, consumers' surplus and social welfare with the leader holding the patent of the innovation are identical to those with the follower holding the patent.

Now, to the question of whether fee licensing or royalty licensing generates a larger welfare to different groups, consider the case when leader is the innovator. As denoted in Kabiraj (2005, pp. 18-19), $Q_1(R)$ and $\Pi_1(R)$ are industry output and profit respectively when only a royalty contract is allowed; similarly, $Q_1(F)$ and $\Pi_1(F)$ are industry output and profit respectively when only a fee contract is allowed. Then comparing industry outputs and profits in the above two situations, we have:

$$Q_1(R) < Q_1(F), \ \Pi_1(R) > \Pi_1(F) \qquad \text{if } \varepsilon < a-c$$

$$Q_1(R) = Q_1(F),\ \Pi_1(R) = \Pi_1(F) \qquad \text{if } \varepsilon \geq a - c$$

The overall welfare comparison[4] yields the following result,

$$W_1(R) < W_1(F) \qquad \text{if } \varepsilon < \frac{2(a-c)}{9} \text{ or } \frac{2(a-c)}{7} \leq \varepsilon < a - c$$

$$W_1(R) > W_1(F) \qquad \text{if } \frac{2(a-c)}{9} \leq \varepsilon < \frac{2(a-c)}{7}$$

$$W_1(R) = W_1(F) \qquad \text{if } \varepsilon \geq a - c$$

Thus combined with the overall welfare comparison when follower is the innovator (see Kabiraj, 2005, p. 19), Proposition 5(b) in Kabiraj (2005, pp. 19-20) should be corrected as follows.

(Revised) Proposition 5(b): Irrespective of the question of which firm innovates, social welfare is larger under a fee contract if either $\varepsilon < \frac{2(a-c)}{9}$ *or* $\frac{2(a-c)}{7} \leq \varepsilon < \frac{(a-c)}{2}$. *When* $\frac{2(a-c)}{9} \leq \varepsilon < \frac{2(a-c)}{7}$, *royalty licensing (fee licensing) will generate a larger welfare if leader (follower) is the innovator, but just the opposite will happen if* $\frac{(a-c)}{2} \leq \varepsilon < a - c$. *However, fee and royalty licensing will generate the same welfare when* $\varepsilon \geq a - c$.

Then Kabiraj (2005) discussed whether leader or follower has a larger incentive for innovation. Consider the case when both fee and royalty licensing contracts are allowed for $\varepsilon < a - c$. Then innovation incentives of leader and follower are as follows.

$$\Phi_1(\varepsilon) = \Pi_1^R - \tilde{\pi}_1^R = \left[\frac{(a-c+\varepsilon)(a-c+3\varepsilon)}{8} + \frac{\varepsilon(a-c-\varepsilon)}{4}\right] - \frac{(a-c-\varepsilon)^2}{8} = \varepsilon(a-c)$$

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[4] It is worthwhile to point out that, if $\frac{2(a-c)}{7} \leq \varepsilon < a - c$, $W_1(F)$ equals the social welfare under no licensing. So, when leader is the innovator, (royalty) licensing not only makes consumers worse off, but also lowers social welfare for $\frac{2(a-c)}{7} \leq \varepsilon < a - c$.

$$\Phi_2(\varepsilon) = \widetilde{\Pi}_2^R - \pi_2^R = \left[\frac{(a-c+3\varepsilon)^2}{16} + \frac{\varepsilon(a-c-\varepsilon)}{2}\right] - \frac{(a-c-\varepsilon)^2}{16} = \varepsilon(a-c)$$

Therefore, contrary to Kabiraj (2005) we have,

$$\Phi_1(\varepsilon) = \Phi_2(\varepsilon) \ \forall\, \varepsilon < a-c$$

This indicates that follower has no more incentives to innovate if both royalty and fee contracts are allowed; in other words, leader has no less incentive to innovate under this situation. When technology transfer is not allowed, or allowed only with fee licensing, leader has strictly a larger incentive to innovate (see Kabiraj, 2005, pp. 21-22). Hence Proposition 6 in Kabiraj (2005, p. 23) should be corrected as follows.

(Revised) Proposition 6: No matter whether technology licensing is allowed or not, in a leadership structure leader has a larger incentive to innovate.[5]

3. Conclusion

In this corrigendum we have corrected the calculation of optimal royalty rate when leader is the innovator, and based on the corrected value some propositions of Kabiraj (2005) have been modified and revised. We find three main results different from those in Kabiraj (2005). First, when both fee and royalty contracts are available, the industry profit, consumers' welfare and social welfare with leader holding the innovation are identical to those with follower holding the innovation. Second, no matter which firm innovates, social welfare is larger under a fee contract if the innovation is quite small or not relatively large. When the innovation size is relatively large, fee licensing will

[5] Since leader comes out with the innovation whenever only fee licensing is allowed or both fee and royalty contracts are allowed, this coincidently supports Proposition 7 in Kabiraj (2005, p. 25).

generate a larger welfare if leader is the innovator and royalty licensing will yield a larger welfare if follower is the innovator. Finally, follower has no more incentives to innovate than leader if both royalty and fee contracts are allowed.

Reference

Kabiraj, T. (2005). ‘Technology transfer in a Stackelberg structure: licensing contracts and welfare’, The Manchester School, Vol. 73, No. 1, pp. 1-28.