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LICENSING CONTRACT IN A STACKELBERG MODEL*

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We study optimal linear licensing and its social welfare implications when the innovator (patentee) is an insider that can make capacity/output commitment so as to act as a Stackelberg leader in the output market. We show that (i) the patentee's profit-maximizing licensing contract is a royalty; (ii) the optimal royalty rate is greater than the cost reduction attained by the licensed technology and is increasing in the number of competitors; (iii) optimal licensing maximizes the likelihood of technology transfer, may reduce social welfare and always makes consumers worse off; and (iv) the innovator benefits from capacity commitment, and the more competitive the output market, the greater the gains it makes by licensing. The opposite holds for consumers.

1 Introduction

Patent licensing is quite widespread and takes place in almost all industries. The common modes of patent licensing are a royalty per unit of output produced with the patented technology, and/or a fixed fee.

The patent licensing literature has analyzed the patentee's profit-maximizing (optimal) licensing contract for two general cases: one, where the patentee is outside the market of operation, i.e. the patentee is not a competitor in the product market; the other where the patentee is inside the market of operation and naturally becomes a competitor in the product market.

In a complete information framework, if the patentee is an outsider, then fixed-fee licensing dominates royalty licensing (Kamien and Tauman, 1986; Katz and Shapiro 1986; Kamien, 1992), whereas in a leadership structure the optimal contract depends on the innovation size (Kabiraj, 2004).[1] Wang (1998) and Kamien and Tauman (2002) analyze the case where the patentee is an insider and competition in the output market is Cournot. They show that royalty licensing dominates fixed fees. Moreover, licensing does not affect consumers and always improves social welfare.

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[1] The outsider then auctions off a fixed number of licenses and finds it more profitable to target cost-reducing inventions to monopolistic industries (Kamien and Tauman, 2002).

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This paper studies optimal licensing within the class of linear contracts, and derives its social welfare implications when the patentee is an insider that can make capacity commitment, as in Mukherjee (2001), and therefore acts as a Stackelberg leader in the output market.[2] The analysis is then particularly relevant for industries that have a dominant firm which is also the (main) innovator.

Specifically, we study an economy with an industry that has a leader owning a cost-reducing innovation and $k \geq 1$ competitors (followers), and technology transfer licensing contracts are feasible.

We show that (i) the optimal licensing contract, the contract that maximizes the leader's profits subject to followers' participation constraints, is a royalty; (ii) the optimal royalty rate is greater than the cost reduction and is increasing in the number of competitors; (iii) optimal licensing maximizes the likelihood of technology transfer, may reduce social welfare and always makes consumers worse off; and (iv) the more competitive the output market, the greater the leader's gains from licensing and the greater the consumers' loss.

We thus have that the optimal licensing contract being a royalty in the insider–innovator case goes beyond the Cournot competition regime (by result (i)). Capacity commitment, i.e. Stackelberg competition, has deep implications on the 'price' of technology transfer and on technology transfer's effects on social welfare and consumer surplus (by results (ii)–(iv)). The leader uses its capacity commitment to restrain its own output and the royalty to restrain followers' outputs. At the optimum, the leader's output falls below the no-licensing status quo, the larger the number of followers the lower the leader's output, and the royalty rate is such that followers find it optimal to produce the same amount they would produce in the absence of license. That is, at the optimum, aggregate output falls and price increases; the more competitive the output market, the bigger these effects. Followers' profits are kept at their outside option value, i.e. what followers would get by rejecting the licensing contract and using the old technology; all the benefits of the technology transfer are reaped by the leader. The leader's benefits come from two sources, the reduction of followers' production costs, because they use the new technology and pay royalties, and the output price increase. Some of the leader's benefits are then at the expense of consumers. However, optimal royalty licensing maximizes industry profits and thereby the likelihood of technology transfer.

Mukherjee (2001) examines the possibility of technology transfer when firms have commitment strategies (incentive delegation/capacity commitment) under the assumption of fixed-fee licensing. Our results suggest that restrictions on licensing contracts reduce the viability of technology transfers.

[2]Erutku and Richelle (2001) deal with non-linear licensing contracts in a Cournotian framework.

In a Stackelberg structure, Kabiraj (2005) studies licensing contracts and welfare, and Wang and Yang (2004) deal with incentives and gains from an innovation when licensing is possible. However, they impose the constraint that the royalty rate cannot exceed the cost reduction. This constraint is redundant in the Cournot framework, but not in a Stackelberg structure. Indeed this paper shows that the unconstrained solution for the royalty violates the constraint imposed in the above-mentioned papers.

The rest of the paper is organized as follows. Section 2 presents the model and derives the no-licensing status quo for the two-firms case. Section 3 derives the optimal licensing in the class of per unit royalty plus fixed-fee contract. Section 4 extends the analysis to n firms, a leader and $n-1$ followers. Section 5 analyzes the case where the follower is the innovator. Conclusions are drawn in Section 6.

2 The Model and the No-licensing Status Quo

Consider a Stackelberg quantity competition model with two firms, a leader (1) and a follower (2), that produce homogeneous goods, the underlying assumption being that firm 1, the leader, can commit capacity. We will also assume that the innovator is the leader.

The demand function is linear:

$$p = 1 - q$$

where p is the price and q is total output. Firms produce at constant unit production cost c_1 and c_2, where $0 < c_i < 1$, $\forall i$.

For any given leader's output q_1, the follower chooses its output q_2:

$$q_2\text{: } \arg_{q2}\max[q_2(p - c_2)] \tag{1}$$

subject to

$$p = 1 - (q_1 + q_2) \tag{2}$$

That is,

$$q_2 = (1 - c_2 - q_1)/2 \tag{3}$$

The leader chooses its output q_1:

$$q_1\text{: } \arg_{q1}\max[q_1(p - c_1)] \tag{4}$$

subject to (2), (3).

Equilibrium outputs, price and profits are

$$q_1 = (1 - 2c_1 + c_2)/2 \tag{5}$$

$$q_2 = (1 + 2c_1 - 3c_2)/4 \tag{6}$$

$$p = (1 + 2c_1 + c_2)/4 \tag{7}$$

$$\Pi_1 = (1 - 2c_1 + c_2)^2/8 \tag{8}$$

$$\Pi_2 = \left[(1 + 2c_1 - 3c_2)^2/4\right]^2 \tag{9}$$

Now, let us consider process innovation by firm 1 that lowers its unit cost by the amount ε and, for convenience, impose that the pre-innovation costs are $c_1 = c_2 = c < 1$. Thus, the (post-innovation) unit cost for firm 1 is $c_1 = c - \varepsilon$, and for firm 2 is $c_2 = c$.

Firm 1 maximizes its profit by accommodating, deterring or blocking entry of firm 2, for any cost reduction $\varepsilon \in [0, c]$.

Entry is accommodated and the follower stays active (i.e. q_2 is positive) provided that

$$(1 - c)/2 > \varepsilon$$

If this inequality is reversed, the leader becomes a monopolist. The above condition separates, in absolute and relative terms, drastic cost reduction (≤), when the more efficient firm becomes the monopolist, from non-drastic (>)[3] cost reduction, when the market keeps being a duopoly.

In the non-drastic case, equilibrium outputs, price and profits are

$$\boldsymbol{q}_1 = (1 - c + 2\varepsilon)/2 \tag{5a}$$

$$\boldsymbol{q}_2 = (1 - c - 2\varepsilon)/4 \tag{6a}$$

$$\boldsymbol{p} = (1 + 3c - 2\varepsilon)/4 \tag{7a}$$

$$\underline{\boldsymbol{\Pi}}_1 = (1 - c + 2\varepsilon)^2/8 \tag{8a}$$

$$\underline{\boldsymbol{\Pi}}_2 = [(1 - c - 2\varepsilon)/4]^2 \tag{9a}$$

For drastic cost reduction:

(i) for $c + \varepsilon > 1$, entry is blocked and the leader sets output equal to monopoly output. Monopoly output, price and profits are given by

$$q_1 = q_M = (1 - c + \varepsilon)/2$$

$$p_M = (1 + c - \varepsilon)/2$$

$$\Pi_M = [(1 - c + \varepsilon)/2]^2$$

(ii) for $c + \varepsilon < 1$, entry is deterred and the leader sets output in excess of the monopoly level to deter the follower from entering. In fact, when $q_1 = (1 - c + \varepsilon)/2$, then $q_2 = (1 - c - \varepsilon)/4 > 0$. So firm 1 must increase its output in order to get $q_2 = 0$:

[3]It is an adaptation of the drastic and non-drastic innovation discussed by Arrow (1962). A drastic innovation arises when the monopoly price, under the new technology, does not exceed the competitive price under the old technology (Kamien and Tauman, 1986, p. 472).

$$q_1 = q_{M1} = 1 - c$$
$$p_{M1} = c$$
$$\Pi_{M1} = \varepsilon(1 - c)$$

We distinguish three cost reduction sizes: small, $\varepsilon < (1 - c)/2$; intermediate, $(1 - c)/2 < \varepsilon < 1 - c$; and big, $1 - c < \varepsilon < c$.

We shall refer to the equilibrium attained for leader's cost $c - \varepsilon$, and follower's cost c, as the no-licensing status quo.

3 The Incentive to License and the Optimal Licensing Contract

We assume that the innovation is observable and verifiable, and similarly for output. Contracts of technology transfer from the leader to the follower are then enforceable and the payments by the recipient can be conditioned on the recipient's output. We shall refer to technology transfer contracts in the same way as licensing contracts, and name the party that makes the technology transfer the licensor and the recipient the licensee. More specifically, a licensing contract states the parties' obligations as follows. The licensor discloses the new technology to the licensee. The licensee pays the licensor a fixed fee and/or a royalty per unit of its output. Contract offers are made by the leader and the follower either rejects the offer or accepts it. If the follower rejects it then it will necessarily use the old technology; if it accepts it then royalty-payment obligations are due independently of the technology used and therefore its profit-maximizing choice is necessarily to adopt the new (cost-reducing) technology. Section 3.3 analyzes the implications that would result if the licensee could renege on its royalty payment obligations on the grounds that it did not use the new technology.

The game played by the leader and the follower is a non-cooperative two-stage game. In the first stage the leader offers a licensing contract, and the follower chooses whether to accept it or reject it. We shall make the conventional assumption that when the follower is indifferent between accepting the leader's licensing offer and rejecting it, it chooses to accept the offer (i.e. it licenses from the leader). In the second stage firms engage in quantity Stackelberg competition. Table 1 below describes the sequence of actions and events.

In what follows we first consider a fixed fee and then the general case of two-part tariff. We will prove that the optimal licensing contract, the contract that maximizes the leader's profits, is a royalty one and that the optimal royalty rate exceeds the cost reduction.

3.1 Fixed-fee Licensing

In this section we consider licensing by means of a fixed fee only. Under this method the leader licenses its new technology to the follower at a fixed fee F

TABLE 1
TIMING OF THE LICENSING GAME

$t = 0$	$t = 1$	$t = 2$	$t = 3$
Contract stage	Leader chooses capacity/output	Follower chooses output	Payoffs are determined. Contract is executed

which entitles it to use the new technology to produce as many units as it wishes.

Imposing $c_1 = c_2 = c - \varepsilon$ into equations (5)–(9), and using the subscript F to denote fee licensing, the firm's equilibrium outputs, price and profits are

$$\boldsymbol{q}_{1\mathrm{F}} = (1-c+\varepsilon)/2 < \boldsymbol{q}_1$$

$$\boldsymbol{q}_{2\mathrm{F}} = (1-c+\varepsilon)/4 > \boldsymbol{q}_2$$

$$\boldsymbol{p}_{\mathrm{F}} = [1+3(c-\varepsilon)]/4 < \boldsymbol{p}$$

$$\underline{\boldsymbol{\Pi}}_{1\mathrm{F}} = q_1(p-c_1) \equiv (1-c+\varepsilon)^2/8$$

$$\underline{\boldsymbol{\Pi}}_{2\mathrm{F}} = q_2(p-c_2) \equiv [(1-c+\varepsilon)/4]^2$$

With non-drastic cost reduction, the maximum fee the leader can charge is such that the follower's profits equal its (no-licensing) status quo payoff $\underline{\boldsymbol{\Pi}}_2$, i.e.

$$F = \underline{\boldsymbol{\Pi}}_{2\mathrm{F}} - \underline{\boldsymbol{\Pi}}_2 = 3\varepsilon(2-2c-\varepsilon)/16$$

The leader's total profits (market profits plus fixed fee) then exceed the profits it makes with no-licensing, i.e. $\underline{\boldsymbol{\Pi}}_{1\mathrm{F}} + F > \underline{\boldsymbol{\Pi}}_1$, if and only if $2(1 - c)/9 > \varepsilon$. The leader will then license its technology if and only if $2(1 - c)/9 > \varepsilon$. This condition is more restrictive than the one required for the cost reduction to be non-drastic.

With drastic cost reduction, the maximum fee the leader can charge is

$$F = \underline{\boldsymbol{\Pi}}_{2\mathrm{F}} - \underline{\boldsymbol{\Pi}}_2 (=0) = [(1-c+\varepsilon)/4]^2$$

and the leader's total income (profits plus fixed fee) is always lower than the (monopoly) profits in the no-licensing status quo. That is:

(i) for $\varepsilon > 1 - c$

$$\underline{\boldsymbol{\Pi}}_{1\mathrm{F}} + F - \Pi_{\mathrm{M}} = -[(1-c+\varepsilon)/4]^2$$

(ii) for $\varepsilon < 1 - c$

$$\underline{\boldsymbol{\Pi}}_{1\mathrm{F}} + F - \Pi_{\mathrm{M1}} = -3[(1-c+\varepsilon)/4^2\varepsilon(1-c)]$$

Hence, with drastic cost reduction, the leader will not license its new technology and it will become a monopolist.

We then have Proposition 1.

Proposition 1: Under a fixed fee, licensing may not occur even though the cost reduction is non-drastic. The leader licenses its innovation to the follower if and only if the cost reduction is sufficiently low so as to satisfy $2(1 - c)/9 > \varepsilon$.

3.2 Two-part Tariff Licensing

We now examine the general case of two-part tariff licensing contracts. The leader licenses the use of the innovation in exchange for a fee, F, and a royalty, r, per unit of output. The leader's profit function is Π_{1T}:

$$\underline{\Pi}_{1T} = q_1(p - c_1) + rq_2 + F$$

Its profit-maximizing choice of output is then q_1:

$$q_1\colon \arg_{q1}\max[q_1(p - c_1) + rq_2] \tag{10}$$

subject to (2), (3).

For any given (c_1, c_2, r), the leader's output is then q_1:

$$q_1 = (1 - 2c_1 + c_2 - r)/2 \tag{11}$$

The follower's output, q_2, is decreasing in the leader's output q_1 (by (3)). When choosing its output, the leader foresees the follower's best response to its output level q_1 and takes into account that the lower q_1, the higher q_2 and hence, for any given royalty rate, the higher its royalty revenue. For any given level of the follower's cost c_2, the leader's output q_1 is decreasing in the royalty rate (by (11)). The follower's cost incorporates the royalty, i.e. $c_2 = c_1 + r$, where $c_1 = c - \varepsilon$, whence (by (11) and (3))

(i) the leader's output is invariant with respect to the royalty rate and identical to the level attained under fixed fee:

$$q_1 = [1 - 2c_1 + (c_1 + r) - r]/2 \equiv (1 - c + \varepsilon)/2 \equiv \boldsymbol{q}_{1F} < \boldsymbol{q}_1 \tag{12}$$

(ii) the follower's output is decreasing in the royalty rate:

$$q_2 = (1 - c_2 - q_1)/2 \equiv [1 - (c_1 + r) - q_1]/2 \equiv (1 - c + \varepsilon)/4 - r/2 \tag{13}$$

(iii) when the cost-reduction is non-drastic, for any royalty rate that exceeds one-half of the cost reduction, i.e. $r > \varepsilon/2$, total output $(q_1 + q_2)$ is strictly smaller than in the no-licensing status quo (by comparing (12)–(13) with (5a)–(6a)).

Summarizing the above results and using the subscript R to denote royalty licensing leads to

$$\boldsymbol{q}_{1R} = (1 - c + \varepsilon)/2$$

$$\boldsymbol{q}_{2R} = [(1 - c + \varepsilon)/4] - r/2$$

$$\boldsymbol{p}_{R} = [(1 + 3c - 3\varepsilon)/4] + r/2$$

$$\underline{\boldsymbol{\Pi}}_{1RT} = \boldsymbol{q}_{1R}[\boldsymbol{p}_{R} - (c - \varepsilon)] + r\boldsymbol{q}_{2R} + F$$

$$\underline{\boldsymbol{\Pi}}_{2R} = \boldsymbol{q}_{2R}[\boldsymbol{p}_{R} - (c - \varepsilon + r)] - F$$

At the first stage, the leader chooses (r, F) in order to maximize its profits subject to the follower's participation constraint, i.e.

$$\text{Max}\underline{\boldsymbol{\Pi}}_{1RT}$$

subject to $\underline{\boldsymbol{\Pi}}_{2R} \geq \underline{\boldsymbol{\Pi}}_{2}$.

At the first best optimum $F \equiv F_{FB} = -\underline{\boldsymbol{\Pi}}_{2} \equiv -[(1 - c - 2\varepsilon)/4]^2$ and $r \equiv r_{FB} = (1 - c + \varepsilon)/2$, which implies $\boldsymbol{q}_{1R} = \boldsymbol{q}_{M}$ (monopoly output), $\boldsymbol{q}_{2R} = 0$. Thus, if the only constraint to the leader's maximization problem is the follower's participation constraint, then the optimum two-part tariff licensing contract implements the monopoly outcome and the leader's profits attain the first-best level. However, the first-best optimal solution requires a negative fee, $F_{FB} < 0$. The leader sets the royalty such that the follower's best response to the leader's monopoly output is not to produce and gives him the positive side payment $|F_{FB}|$ so that the follower's payoff does not fall below what it gets in the no-licensing status quo.

Under the (reasonable) restriction that side payments cannot be made (as, for example, in Katz and Shapiro (1985) and in Sen and Tauman (2002)), i.e. (explicit) collusive behavior is forbidden, the first best cannot obtain and the leader's problem is

$$\text{Max}\underline{\boldsymbol{\Pi}}_{1RT}$$

subject to $\underline{\boldsymbol{\Pi}}_{2R} \geq \underline{\boldsymbol{\Pi}}_{2}$, and r, $F \geq 0$.

The solution is the second-best optimum where the non-negative constraint on F and the follower's participation constraint are both binding, i.e. $F = 0$, and $\underline{\boldsymbol{\Pi}}_{2R} = \underline{\boldsymbol{\Pi}}_{2}$. The solution to the leader's optimization problem is then a pure royalty licensing contract ($F = 0$, $r = r^*$), and the optimal royalty rate r^* is such that the follower's participation constraint holds at equality, i.e. $\underline{\boldsymbol{\Pi}}_{2R} = \underline{\boldsymbol{\Pi}}_{2}$.[4]

Specifically, if the cost reduction is non-drastic, then $r^* \equiv 1.5\varepsilon$, where $r^* < r_{FB}$; and if the cost reduction is drastic, i.e. $\underline{\boldsymbol{\Pi}}_{2} = 0$, then $r^* =$

[4]This follows because the derivative of the leader's objective function with respect to r evaluated at r^* is strictly positive, i.e. at the optimum the follower's participation constraint is binding.

$(1 - c + \varepsilon)/2 \equiv r_{FB}$, i.e. the monopoly outcome is attained (with and without licensing).[5]

In the relevant case, i.e. when the cost reduction is non-drastic, the optimal royalty rate falls below the first best level r_{FB}, but it exceeds the cost reduction $c_2 - c_1$. This also implies that total output (price) is lower (higher) than what would obtain with no licensing. Indeed, for non-drastic cost reduction, substituting $r = r^* \equiv 1.5\varepsilon$ in ($\boldsymbol{q}_{1R}$, $\boldsymbol{q}_{2R}$, $\boldsymbol{p}_R$, $\underline{\boldsymbol{\Pi}}_{1RT}$, $\underline{\boldsymbol{\Pi}}_{2R}$) leads to

$$\boldsymbol{q}_{1R} = (1 - c + \varepsilon)/2 \equiv \boldsymbol{q}_{1F} < \boldsymbol{q}_1$$

$$\boldsymbol{q}_{2R} = (1 - c - 2\varepsilon)/4 \equiv \boldsymbol{q}_2 < \boldsymbol{q}_{2F}$$

$$\boldsymbol{p}_R = (1 + 3c)/4 > \boldsymbol{p} > \boldsymbol{p}_F$$

$$\underline{\boldsymbol{\Pi}}_{1RT} = \left[(1 - c + \varepsilon)^2/8\right] + 3\varepsilon(2 - 2c - \varepsilon)/8 = \underline{\boldsymbol{\Pi}}_{1F} + 2F > \underline{\boldsymbol{\Pi}}_1$$

$$\underline{\boldsymbol{\Pi}}_{2R} = [(1 - c - 2\varepsilon)/4]^2 = \underline{\boldsymbol{\Pi}}_2$$

The output of the leader and that of the follower are, respectively, lower and equal to the levels attained with no licensing, whereas the output price is higher. The leader's total profits (market profits plus royalties) are higher than with no licensing and they exceed what it would obtain by licensing with a fixed fee.

The intuition for the results is as follows. The non-negative constraint on fees, $F \geq 0$, forbids the leader to set the royalty sufficiently high so that the follower's best response to the leader's monopoly output is that of being inactive. In the second-best optimum, the leader sets its output above the monopoly level but below the no-licensing status quo and sets the royalty above the cost reduction so that the follower finds it optimal to produce exactly as in the no-licensing status quo. The follower faces a *de facto* unit cost increase, because of the royalty, and produces the same level of output. Nevertheless, its profits are the same as in the no-licensing status quo: the price increase, which results from the overall output reduction, offsets the follower's unit cost increase exactly. The leader gains from the price increase. This explains why royalty licensing dominates fixed-fee licensing.

[5]In fact the incentive to license is also present in the drastic intermediate cost reduction case when $c + \varepsilon < 1$. In this case the leader offers a licensing contract to the second firm in exchange for a royalty rate:

$$r^* = (1 - c + \varepsilon)/2$$

The leader produces the monopoly output

$$q_1 = q_M = (1 - c + \varepsilon)/2$$

at price $p_M = (1 + c - \varepsilon)/2$, and its profits are $\Pi_M = [(1 - c + \varepsilon)/2]^2$. The second firm still produces zero quantity, $q_2 = 0$, but, with respect to the status quo licensing case, the first firm produces the monopoly quantity and not the limit quantity, $q_1 > q_M$, in order to get $q_2 = 0$.

The sequencing of moves with royalty licensing acts as an implicit collusive device. The sequencing of moves (which is embedded in the Stackelberg leader game) helps coordination, and the appropriate royalty exploits this coordination and implements implicit though partial collusion: aggregate output falls below the competitive level but not to the extent of reaching the monopoly outcome. This result complements Faulì-Oller and Sandonìs (2002) who show that the royalty may act as a collusive device when there is product differentiation and Bertrand competition.

We then have Proposition 2.

Proposition 2: The optimal licensing contract is a royalty, the optimal royalty rate exceeds the cost reduction, and technology transfer occurs whenever the cost reduction is non-drastic. Aggregate output (price) is lower (higher) than in the no-licensing status quo.

Proposition 2 implies the following corollaries.

Corollary 1: Licensing makes consumers worse off and it may lower social welfare.

That licensing makes consumers worse off follows directly from Proposition 2, i.e. total output is lower and the price is higher. Social welfare, the sum of consumer surplus and firms' profits, may shrink because the no-licensing social welfare

$$(3-3c+2\varepsilon)^2/32+(1-c+2\varepsilon)^2/8+[(1-c-2\varepsilon)/4]^2$$

is larger than that attained with licensing:

$$\tfrac{1}{2}[(3-3c)/4]+(1-c+\varepsilon)^2/8+3\varepsilon(2-2c-\varepsilon)/8+[(1-c-2\varepsilon)/4]^2$$

whenever $\varepsilon > (1-c)/7$.

These results do not hold in the Cournot case, because with Cournot competition the optimal royalty equals the cost reduction. Total output and price are then exactly the same as in the no-licensing status quo; licensing does not affect consumers and improves social welfare because the patentee makes greater total profits thanks to the royalty revenue (Wang, 1998).

Corollary 2: Technology transfer is less likely under fixed-fee licensing than under royalty licensing, and the leader (consumers) is worse off (better off) under fixed-fee licensing than under optimal royalty licensing.

This follows directly from Propositions 1 and 2. Indeed, the leader enjoys a cost advantage under royalty licensing while the two firms compete on equal costs under fee licensing. Hence, the leader reaps the reward of licensing while still enjoying its cost advantage under royalty licensing. The leader's benefits are at the expense of consumers: the price is higher under royalty licensing. However, industry profits are greater under royalty licensing: royalty licensing maximizes the likelihood of technology transfer. This also suggests that restrictions on licensing contracts limit the viability of technology transfers.

3.3 Limitations to Contract Enforceability

This section derives the implications that would result from limitations to contract enforceability, and specifically from the possibility that the licensee, after having signed the contract, reneges on its contractual royalty obligations on the grounds that it did not use the new technology. This possibility implies that the follower fulfills its contractual obligations if and only if it finds it optimal to use the new technology. This adds to the licensor's optimization problem the constraint that the royalty rate cannot exceed the cost reduction, i.e.

$$r \le \varepsilon$$

In the case of a non-drastic innovation, the constraint on the royalty rate turns out to be binding. The solution is

$$r = \varepsilon$$

$$F = [(1-c-\varepsilon)/4]^2 - [(1-c-2\varepsilon)/4]^2 > 0$$

Indeed, for non-drastic cost reduction, substituting $r = r^* \equiv \varepsilon$ in ($\boldsymbol{q}_{1\mathrm{R}}$, $\boldsymbol{q}_{2\mathrm{R}}$, $\boldsymbol{p}_{\mathrm{R}}$, $\underline{\boldsymbol{\Pi}}_{1\mathrm{RT}}$, $\underline{\boldsymbol{\Pi}}_{2\mathrm{R}}$), using the subscript R′ to denote royalty licensing when $r = \varepsilon$, leads to

$$\boldsymbol{q}_{1\mathrm{R}'} = (1-c+\varepsilon)/2 \equiv \boldsymbol{q}_{1\mathrm{R}} < \boldsymbol{q}_1$$

$$\boldsymbol{q}_{2\mathrm{R}'} = (1-c-\varepsilon)/4 > \boldsymbol{q}_2 \equiv \boldsymbol{q}_{2\mathrm{R}}$$

$$\boldsymbol{p}_{\mathrm{R}'} = (1+3c-\varepsilon)/4 \qquad \boldsymbol{p}_{\mathrm{R}} > \boldsymbol{p}_{\mathrm{R}'} > \boldsymbol{p}$$

$$\underline{\boldsymbol{\Pi}}_{1\mathrm{RT}'} = \left[(1-c+\varepsilon)^2/8\right] + 3\varepsilon(2-2c-\varepsilon)/8 + \varepsilon(1-c+\varepsilon)/8 > \underline{\boldsymbol{\Pi}}_{1\mathrm{RT}} > \underline{\boldsymbol{\Pi}}_1$$

$$\underline{\boldsymbol{\Pi}}_{2\mathrm{R}'} = [(1-c-2\varepsilon)/4]^2 = \underline{\boldsymbol{\Pi}}_2 = \underline{\boldsymbol{\Pi}}_{2\mathrm{R}}$$

Most of the results derived above still hold true with the restriction $r \le \varepsilon$.

In Proposition 2, for example, total output (price) is still lower (higher) than in the no-licensing status quo. The results on welfare in Corollary 1 remain unchanged, and consumers are still worse off with royalty licensing than with fixed fees only. The results in Corollary 2 are also unchanged, since royalty licensing makes the licensor better off. Moreover, royalty licensing has the same collusive effect pointed out above. That is, it improves the leader's surplus at the expense of consumers and hence at the cost of reduced efficiency.

4 A Leader and $k > 1$ Followers

In this section we extend the analysis to n firms; firm 1 is the leader, firms 2, 3, . . . , n are symmetric followers. With no loss of generality, we shall derive the optimal licensing policy (the optimal licensing contract and the extent of licensing), and the associated equilibrium outcome under the assumption that the cost reduction satisfies

$$(1-c)/n > \varepsilon$$

which implies that all the leader's competitors will be active.[6]

In the no-licensing status quo, equilibrium outputs, price and profits are

$$\boldsymbol{q}_1 = (1-c+n\varepsilon)/2$$

$$\boldsymbol{q}_i = (1-c-n\varepsilon)/2n \qquad i = 2, 3, \ldots, n$$

$$\boldsymbol{p} = [1+c(2n-1)-\varepsilon n]/2n$$

$$\underline{\boldsymbol{\Pi}}_1 = (1-c+n\varepsilon)^2/4n$$

$$\underline{\boldsymbol{\Pi}}_i = [(1-c-n\varepsilon)/2n]^2 \qquad i = 2, 3, \ldots, n$$

By the same reasoning as in Section 3, licensing makes the leader better off and the licensing contract that maximizes its profits is a royalty. However, with more than one follower, the leader also has a choice about the number of competitors to give licenses to. The economic intuition would suggest that it finds it optimal to give licenses to all competitors, since by so doing it fully reaps the benefits of the cost reduction. We prove below that this is indeed the case.

Suppose the leader gives licenses to firms 2, 3, . . . , j, where $j \leq n$. Then it maximizes its profits, subject to the participation constraints of the licensees, by setting a zero fixed fee and the royalty rate to $r^*(j)$:

$$r^*(j) = [\varepsilon(2n-j+1)]/2(n-j+1)$$

Let $\underline{\boldsymbol{\Pi}}_{1\mathrm{R}(j)\mathrm{T}}$ denote the leader's (maximized) profits, conditionally upon granting optimal royalty licenses to firms 2, 3, . . . , j, where $j \leq n$; i.e. firms 2, 3, . . . , j all have licenses that set the royalty rate to the leader's profit-maximizing level $r^*(j)$; $\underline{\boldsymbol{\Pi}}_{1\mathrm{R}(j)\mathrm{T}}$ is given by

$$\underline{\boldsymbol{\Pi}}_{1\mathrm{R}(j)\mathrm{T}} = \{1-c+[\varepsilon n^2/(n-j+1)][1-c+\varepsilon(n-j+1)] + [\varepsilon(2n-j+1)(j-1)(1-c-n\varepsilon)]/(n-j+1)\}/4n$$

[6] If $(1-c)/n < \varepsilon$, then (i) for $(1-c)/2 < \varepsilon$ the cost reduction is drastic and the leader is a monopolist; (ii) if $(1-c)/2 > \varepsilon$, then at an equilibrium k followers are active and make zero profits, where k solves $(1-c)/(k+1) = \varepsilon$, i.e. $1 < k < n-1$. The equilibrium is as that derived in the text; simply redefine n as $n = k+1$.

The leader's problem amounts to choosing j so as to

$$\text{Max}\underline{\boldsymbol{\Pi}}_{1\text{R}(j)\text{T}}$$

subject to $j \le n$.

The derivative of the leader's profits with respect to j is always strictly positive, i.e. the constraint $j \le n$ binds, and therefore the solution to the maximization problem is $j^* = n$.

This establishes that the leader's optimal choice is that of giving licenses to all followers and setting the royalty rate to r^*:

$$r^* = [\varepsilon(n+1)]/2$$

At the optimum, equilibrium outputs, price and profits are

$$\begin{aligned}
\boldsymbol{q}_{1\text{R}} &= (1-c+\varepsilon)/2 \\
\boldsymbol{q}_{i\text{R}} &= (1-c-n\varepsilon)/2n \qquad i = 2, 3, \ldots, n \\
\boldsymbol{p}_{\text{R}} &= [1+c(2n-1)+\varepsilon n(n-2)]/2n > \boldsymbol{p} \\
\underline{\boldsymbol{\Pi}}_{1\text{RT}} &= \left\{(1-c+\varepsilon)^2 + \varepsilon(n^2-1)[2(1-c)-\varepsilon(n-1)]\right\}/4n \\
\underline{\boldsymbol{\Pi}}_{i\text{R}} &= \underline{\boldsymbol{\Pi}}_i \qquad i = 2, 3, \ldots, n
\end{aligned}$$

where $\underline{\boldsymbol{\Pi}}_{i\text{R}} = \underline{\boldsymbol{\Pi}}_i$, $i = 2, \ldots, n$, simply follows because the leader's profit-maximizing licensing contract satisfies followers' participation constraints at equality.

Comparing equilibrium outputs, price and profits with the no-licensing status quo leads to

$$\begin{aligned}
\Delta\boldsymbol{q}_1 &\equiv \boldsymbol{q}_{1\text{R}} - \boldsymbol{q}_1 = -\varepsilon(n-1)/2 \\
\Delta\boldsymbol{q}_i &\equiv \boldsymbol{q}_{i\text{R}} - \boldsymbol{q}_i = 0 \qquad i = 2, 3, \ldots, n \\
\Delta\boldsymbol{p}_{\text{R}} &\equiv \boldsymbol{p}_{\text{R}} - \boldsymbol{p} = r^* - \varepsilon = \varepsilon(n-1)/2 \\
\Delta\underline{\boldsymbol{\Pi}}_1 &\equiv \underline{\boldsymbol{\Pi}}_{1\text{RT}} - \underline{\boldsymbol{\Pi}}_1 = \varepsilon(n-1)[2(1-c)-\varepsilon(n+1)]/4 \\
\Delta\underline{\boldsymbol{\Pi}}_i &\equiv \underline{\boldsymbol{\Pi}}_{i\text{R}} - \underline{\boldsymbol{\Pi}}_i \qquad i = 2, 3, \ldots, n
\end{aligned}$$

The leader sets its output lower than in the no-licensing status quo; the larger n, the lower the leader's output, i.e. $\Delta\boldsymbol{q}_1 < 0$, and $|\Delta\boldsymbol{q}_1|$ is increasing in n. It sets the royalty rate such that the best response of follower i, $i = 2, 3, \ldots, n$, is to produce the same output level as in the no-licensing status quo: the royalty rate exceeds the cost reduction and is increasing in n. The leader's gains from licensing, $\Delta\underline{\boldsymbol{\Pi}}_1$, are strictly positive and increasing in n (by $n > 1$ and $(1-c)/n > \varepsilon$). The opposite holds for consumers, since they pay a higher price than in the no-licensing status quo; the larger is n, the higher the price.

We then have Proposition 3.

Proposition 3: Let there be n firms, one leader and $n - 1$ followers. The leader maximizes its profits by giving licenses to all competitors, and the optimal licensing contract is a royalty. The royalty rate exceeds the cost reduction and is increasing in the number of followers. The more competitive the output market, the more the leader benefits from licensing. The reverse holds for consumers.

5 The Follower Is the Innovator

We consider the case where the follower is the innovator. Licensing is feasible, but by contrast to the analysis above the innovator (follower) cannot make capacity/output commitment.

Along the lines followed above, we first consider fixed-fee licensing and then two-part tariff licensing.

With non-drastic cost reduction, the maximum fee the follower can charge is (the subscript i denotes that the follower is the innovator):

$$F = \underline{\boldsymbol{\Pi}}_{1\mathrm{F}} - \underline{\boldsymbol{\Pi}}_{1\mathrm{i}} = \varepsilon(1-c)/2$$

where $\underline{\boldsymbol{\Pi}}_{1\mathrm{i}} \equiv (1 - c - \varepsilon)^2/8$ is the leader's payoff in the no-licensing status quo, i.e. $\underline{\boldsymbol{\Pi}}_{1\mathrm{i}}$ is identical to $\Pi_1 \equiv (1 - 2c_1 + c_2)^2/8$ as given by (4) for $c_1 = c$ and $c_2 = c - \varepsilon$. The follower's total income (profits plus fixed fee) is larger than the profits it makes in the no-licensing status quo, i.e. $\underline{\boldsymbol{\Pi}}_{2\mathrm{F}} + F > \underline{\boldsymbol{\Pi}}_2$, if and only if $(1 - c)/2 > \varepsilon$. The follower will then license its new technology if and only if $(1 - c)/2 > \varepsilon$, which is more restrictive than the condition required for the cost reduction to be non-drastic.[7]

We now examine two-part tariff licensing contracts. Solving for equilibrium outputs and profits, for any given royalty rate r, yields

$$\boldsymbol{q}_{1\mathrm{R}'} = (1-c+\varepsilon-2r)/2$$

$$\boldsymbol{q}_{2\mathrm{R}'} = (1-c+\varepsilon+2r)/4$$

$$\boldsymbol{p}_{\mathrm{R}'} = (1+3c-3\varepsilon+2r)/4 = \boldsymbol{p}'$$

$$\underline{\boldsymbol{\Pi}}_{1\mathrm{R}'} = (1-c+\varepsilon-2r)^2/8 - F$$

$$\underline{\boldsymbol{\Pi}}_{2\mathrm{R}'} = [(1-c+\varepsilon+2r)/4]^2 + [r(1-c+\varepsilon-2r)/2] + F$$

where $\boldsymbol{p}'$ is the output price in the no-licensing status quo.

The solution to the follower's optimization problem is again a pure royalty contract ($F = 0$, $r = r^*$), where the optimal royalty rate r^* is the rate that maximizes the follower's profits subject to the leader's participation con-

[7]The condition for the leader to be active (non-drastic innovation) is $1 - c > \varepsilon$.

straint holding at equality ($\boldsymbol{\Pi}_{1R} = \boldsymbol{\Pi}_{1i}$). The optimal royalty rate is $r^* = \varepsilon$, i.e. it is identical to the cost reduction. Total output and price are then identical to the levels attained in the no-licensing status quo. We then have that, in the absence of capacity/output commitment by the patentee, licensing does not affect consumers and improves social welfare because the innovator earns greater total profits thanks to the royalty revenue.

We then have Proposition 4.

Proposition 4: If the innovator is the follower, i.e. it cannot make capacity/output commitment, then it licenses whenever the cost reduction is non-drastic; it becomes a monopolist if the reverse is true. The licensing contract that maximizes the follower's profits is a royalty, and the royalty rate equals the cost reduction. Licensing does not affect consumers and improves social welfare.

By contrast to the leader, the follower (as well as Cournot competitors) cannot commit to restrain output; the licensee's participation constraint then requires the royalty rate not to exceed the cost reduction. Lack of capacity/output commitment makes consumers better off, and the innovator worse off. This also implies that the incentives to innovate are greater when the innovator can commit capacity; the larger the number of competitors, the greater the gains from committing capacity (by Propositions 3 and 4).

6 Conclusion

In the class of per unit royalty plus fixed-fee contract, we have studied optimal licensing and its social welfare implications when the innovator (patentee) is an insider and can make capacity commitment, i.e. it acts as a Stackelberg leader in the output market.

We have shown that (i) the optimal licensing contract, the contract that maximizes the leader's profits subject to followers' participation constraints, is a royalty; (ii) the optimal royalty rate exceeds the cost reduction attained by the licensed technology and is increasing in the number of competitors; (iii) optimal licensing maximizes the likelihood of technology transfer, may reduce social welfare and always makes consumers worse off; and (iv) the innovator benefits from capacity commitment, and the more competitive the market the greater the gains it makes by licensing. The opposite holds for consumers.

Result (i) complements the result in Wang (1998) and Kamien and Tauman (2002) who derive the optimal licensing contract for an insider under Cournot competition and show that the optimal contract is a royalty. Thus capacity commitment does not affect the type of the licensing contract. However, it has deep implications for the 'price' of technology transfer and for technology transfer's effects on social welfare and consumer surplus. In the absence of capacity commitment, the optimal royalty rate equals the cost reduction and consequently licensing does not affect consumers and always improves social welfare (Wang, 1998; Kamien and Tauman, 2002). By contrast, when the innovator can commit capacity the royalty rate exceeds the cost reduction and is higher the more competitive the output market is. The leader sets its output below the no-licensing level; the larger the number of followers the lower the leader's output; the royalty rate is set such that followers find it optimal to produce the same amount they would produce in the absence of license. That is, aggregate output falls and the price increases, the more so the more competitive is the output market. Then some of the benefits that the leader gets from technology transfer are at the expense of consumers. However, industry profits and the likelihood of technology transfer are maximized under royalty licensing.

We have studied the implications if the licensee could renege on its royalty payment obligations whenever it did not make use of the new technology and have shown that most results still hold true with the restriction that the royalty rate does not exceed the cost reduction.

Our analysis suggests that capacity commitment with technology transfer makes consumers worse off and may reduce social welfare. However, this conclusion holds for exogenous innovations. The greater the profits, the greater the incentives to innovate. Our analysis then suggests that innovations are more likely when the innovator can commit capacity and can license its innovation, and the more so the more competitive is the output market. Moreover, we have shown that royalty licensing maximizes the likelihood of technology transfer and that restrictions on licensing contracts reduce the viability of technology transfers.

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