Per-unit versus ad-valorem royalty licensing in a Stackelberg market

Antelo, Manel and Bru, Lluís

Universidade de Santiago de Compostela, Universitat de les Illes Balears

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Manel Antelo

Universidade de Santiago de Compostela (Spain)

and

Lluís Bru

Universitat de les Illes Balears (Spain)

Abstract

We consider licensing of a non-drastic innovation by a patentholder who interacts with a potential licensee in a Stackelberg duopoly. We compare per-unit and ad-valorem royalty contracts, showing why and when each licensing deal should be observed. We find that ad-valorem royalty is preferred by a licensor that plays as the leader, but per-unit royalty is more profitable if the licensor is the follower. We also find that only innovations that do not hurt consumers are socially beneficial. Finally, licensor's leadership or followership and innovation size determine licensing impact on the incentive to disseminate an innovation.

Keywords: Licensing, leader and follower, welfare

1. Introduction

Empirical evidence on licensing deals indicate that innovators often act as incumbent manufacturers that transfer their patented innovations to direct competitors (Jiang and Shi, 2018) and that most licensing contracts feature positive royalties (Bousquet et al., 1998). A patent licensing survey performed in 2007 by the OECD found that 20% and 29% of respondent firms in Europe and Japan, respectively, out-licensed patents to non-affiliated partners (Zuniga and Guellec, 2009). Another similar survey conducted by the European Commission (Radauer and Dudenbostel, 2013) reported that 56% of European patent-holding firms were currently engaged in out-licensing activities, while another 16% planned to consider this option for the future. As an example of the importance of licensing as a crucial revenue source for firms, Nokia's reported brand and technology licensing net sales amounted to 1.6 billion euros in 2017 (Nokia Corporation Financial Report, 2018). Licensing is also a powerful value driver for companies like Microsoft, Ericsson, IBM, Qualcomm, and Texas Instruments (Hoffman, 2014).

Since the main motivation of innovative firms for licensing out their patents is to earn revenue, they will try to devise a licensing arrangement that provides the maximum payoff. The empirical literature shows that contingent royalties, either per-unit royalty (non-negative uniform royalty per unit of production) or ad-valorem royalty (non-negative royalty based on a percentage of licensee sales), are commonly included in licensing contracts (Bousquet et al., 1998; Lim and Veugelers, 2003; Trombini and Comacchio, 2012). The theoretical literature shows that the rationale for this practice lies in factors such as demand or cost uncertainty (Bousquet et al., 1998), product differentiation, a licensee's new product development cost (San Martín and Saracho, 2016), or the relative efficiency of the licensee compared to the licensor (Fan et al., 2018). San Martín and Saracho (2010), for instance, found that, under full information, an ad-valorem royalty was the preferred licensing contract for an incumbent licensor in a Cournot industry. This is because, with the aim of alleviating downward pressure on price by reducing licensee costs due to the new transferred technology, ad-valorem royalties compared to per-unit royalties allow the licensor to relax market competition. Likewise, Fan et al. (2018) find that, in a Cournot duopoly, per-unit licensing is more profitable if the licensor is more efficient than the licensee in using the innovation, whereas ad-valorem licensing is more profitable in the reverse scenario.

This paper is motivated by the belief that many key industries may be better described by Stackelberg leadership rather than Cournot oligopoly (Fjell and Heywood, 2002).[1] Our work, in

[1] This may be the case of former state monopolies that faced increased competition once the market was fully opened up, e.g., telecommunications, electricity, post, etc, dominated by former public monopolies with a first-mover advantage.

exploring how licensors behave in those industries when choosing a licensing scheme,[2] contributes three findings to the literature.

First, the kind of royalty crucially depends on the licensor's status as a leader or follower. Particularly, the superiority of ad-valorem over per-unit royalty under Cournot no longer holds when the licensor competes with a rival that plays as a leader making a capacity/output commitment. In this case, the licensor's total payoff (i.e., its own profit plus its licensing income) is a constant function of the ad-valorem royalty and, irrespective of the royalty rate chosen, is inferior to what it would be if per-unit royalty was used. The intuition is as follows. Given the market position of each firm, the licensee produces a large quantity and the licensor a small quantity. The licensor, therefore, by including per-unit royalty in the contract, does not cause the licensee's production to vary (production increases because of cost reductions, but decreases because of the royalty rate), while the fact that the licensee's production continues to be high as a leader increases the licensor's external revenue. In contrast, ad-valorem royalty would increase the licensee's production by the cost reductions implied by the new technology, which, considering that production is already raised by the fact of market leadership, would lead the licensor to produce very small quantities and obtain very reduced internal profits. Thus, per-unit royalty functions as a commitment of the licensor to make the market more collusive than would be the case with ad-valorem royalty.

Our second finding is related to the licensing impact on welfare. While, in a Cournot setting, licensing as compared to no licensing unequivocally hurts both consumers and society (San Martín and Saracho, 2010), in a Stackelberg environment the licensing impact on consumers and society as a whole depends on the licensor's status in the marketplace. The diffusion of an innovation harms consumers and society only when the licensor is the leader; this is because the market becomes more collusive due to the ad-valorem royalty licensing scheme. If the licensor plays as a follower, however, per-unit royalty is used to license the innovation, and while consumer surplus remains unaltered, society as a whole is better off in welfare terms after licensing.[3]

Finally, we find that the incentive to undertake innovative activities and license an innovation largely depends on both the licensor's market status and the size of the innovation. A small innovation can only have a large impact on the patentholder's profit if the patentholder already has a large market share (i.e., is a leader), while a large innovation can have a large impact

[2] Filippini (2005) examined licensing in a Stackelberg model but restricted the analysis to a licensor that acts as a leader in the output market and uses per-unit royalty as the licensing scheme.

[3] Kabiraj (2005), in studying optimal licensing contracts in a leadership structure along with the welfare implications, shows that aggregate welfare depends on the types of contracts available and on ownership of the patent. In particular, there are situations when a follower's innovation generates larger welfare than a leader's innovation.

on the market share of a small firm (follower firm), but not on that of a leader firm. Thus, when the size of the innovation is sufficiently small, the incentive to innovate and disseminate their innovation is higher for a leader innovator than for a follower innovator, while the opposite holds for a large innovation.

Stackelberg competition, which is the assumed basis for this paper, fits well with real-world industries where some manufacturers, possibly with internal R&D divisions, may or may not have a hold over others in terms of setting the quantity to be produced in the market. Asymmetry may be motivated, for example, by differently sized or aged firms. Concerning size, the literature does not provide clear-cut results on the relationship between firm size and innovation and, although the tendency seems to be positive, it is not necessarily linear. According to Acs and Audrestch (1987, 1990), the relationship depends on industry characteristics: in highly concentrated sectors with high entry barriers, large firms more than small firms tend to innovate (and become licensors), whereas the opposite holds for less concentrated sectors reflecting emerging or growing technologies. As for the relationship between innovation and firm age, the evidence indicates that challengers invest more in R&D than incumbents when the goal is to enter new markets (Reinganum, 1983, Czarnitzki and Kraft, 2004); this suggests that older firms may be less R&D-intensive than their younger counterparts. In this spirit, some scholars have even pointed out that the innovative contribution of new firms is so valuable that industrial policy should subsidize entrants while taxing incumbents (Acemoglu et al., 2013). However, Coad et al. (2016) find that investment in innovation by young firms appears to be significantly riskier than that by more mature firms. Huergo and Jaumandreu (2004) find that the probability of innovating varies widely by activity, that small size per se broadly reduces the probability of innovation, and that entrant firms are more likely to innovate than older firms. Summing up, a firm that plays as either a leader or a follower can be assumed to innovate.

The rest of the paper is structured as follows. Section 2 outlines the model, Section 3 examines the preferred method – ad-valorem royalty or per-unit royalty – for licensing the innovation, Section 4 analyses the impact of licensing on welfare, Section 5 describes incentives to undertake R&D and disseminate innovations, and finally, Section 6 concludes.

2. The model

Consider a Stackelberg duopoly industry with firms 1 and 2 producing a homogenous good. Consumers in this market exhibit the following linear piecewise demand function:

$$p(Q) = \max\ \{0, a - Q\} \quad \text{with } Q = \sum_{i=1}^{2} q_i, \tag{1}$$

where q_i denotes the quantity produced by firm i ($i = 1, 2$) and parameter $a > 0$ represents the market size. Firms produce the good with their existing technology, which leads them to have the constant marginal cost c, $c \in (0, a)$. There are no fixed costs of production. One of the firms in the industry owns an R&D division that develops an innovation which reduces the marginal cost from c to 0.

Throughout this paper we make the following assumption concerning the cost reduction induced by the innovation:

Assumption 1. *The size of the innovation, c, is such that* $0 < c < a/3$.

This assumption ensures that all firms are previously active even if licensing does not take place or, alternatively, that the innovation is non-drastic irrespective of whether the owner behaves as a leader or follower in the market. As a result, non-licensing of the innovation does not give rise to a monopoly.

The innovative firm can license its innovation to a rival by means of a contract that consists of a non-negative uniform royalty per unit of production (per-unit royalty), or a non-negative royalty based on a percentage of sales (ad-valorem royalty).[4] The marginal cost of selling a licence is zero. The rival acquires the innovation if profit after payments is larger than that obtained without the licence; it is thus operating at marginal cost c against the innovative firm with zero marginal cost.

The analysis follows a four-stage non-cooperative game. In the first stage, the innovator, either a market leader or follower, decides whether or not to license the innovation to its rival and, in the case of licensing, offers either a per-unit royalty contract or an ad-valorem royalty contract. In the second stage, the rival, either the follower or leader in setting the output level, accepts or refuses the licensor's offer. If the offer is accepted, then, in the third stage, the leading manufacturer chooses its level of production. In the fourth stage, the follower observes the output level of the leader and decides their own quantity. As usual, we look for a subgame Nash perfect equilibrium for this licensing game.

3. The licensor's decision

[4] Licensing by means of a fixed-fee contract is not considered because this mechanism is never optimal for the licensor, irrespective of licensor status in the marketplace. Likewise, the optimal two-part tariff contract consisting of per-unit or ad-valorem royalty plus a non-negative fixed fee features a zero fee in both cases.

3.1 The licensor plays as leader

In this section we consider a leader's innovation. In this case, if licensing takes the form of a per-unit contract with royalty rate r, $r \leq c$,[5] and the licensee accepts the licensor's offer, then, in the fourth stage of the game, once the licensor chooses to produce q_L, the licensee faces the problem:

$$q_l = \operatorname{argmax} \pi_l^u = (a - r - q_L - q_l)q_l \tag{1}$$

where superscript u denotes per-unit royalty and subscripts L and l refer to the licensor and licensee, respectively. Solving Eq. (1) affords $q_l(q_L) = (a - r - q_L)/2$. The licensor's optimal quantity is then given by:

$$q_L = \operatorname{argmax} \pi_L^u = (a - q_L - (a - r - q_L)/2)q_L + r\,(a - r - q_L)/2 \tag{2}$$

This yields quantities $q_L = a/2$ and $q_l = (a - 2r)/4$ and licensee's profit $\pi_l^u(r) = \left(\frac{a-2r}{4}\right)^2$. In the second stage, the licensee accepts the licensor's offer whenever this profit is larger than that which would be obtained using the old technology, in which case the licensor would produce the quantity $q_L^n = (a + c)/2$, and the licensee would produce the strictly positive quantity[6] $q_l^n = (a - 3c)/4$, where superscript n stands for no licence. As a result, the licensee's profit amounts to $\pi_l^n = \left(\frac{a-3c}{4}\right)^2$ and the licensor charges the per-unit royalty that solves:

$$\max_r \pi_L^u = \frac{a(a+2r)}{8} + \frac{r(a-2r)}{4}, \text{ s.t: } \pi_l^u(r) \geq \pi_l^n \text{ and } r \leq c \tag{3}$$

Note that $r \leq c$ implies that $\pi_l^u(r) > \pi_l^n$. Under per-unit royalty, and whenever the licensor is the market leader, a linear contract limits the rent extraction of the licensor and forces them to leave some rents to the licensee. The solution to Eq. (3) is therefore $r = c$, provided that Assumption 1 is satisfied. This leads the licensor's payoff to be:

$$\pi_L^u = \frac{a^2 + 4c(a-c)}{8} \tag{4}$$

Assume now that the licence is an ad-valorem royalty contract d, $0 < d < 1$, whereby the licensee's payment will be proportional to sales. The licensee chooses to produce the quantity:

$$q_l = \operatorname{argmax} \pi_l^v = (1 - d)(a - q_L - q_l)q_l \tag{5}$$

where superscript v denotes ad-valorem royalty. The solution to Eq. (5) leads to $q_l(q_L) = (a - q_L)/2$. In turn, the licensor selects:

[5] The follower could accept a per-unit royalty rate $r > c$ if this led to a sufficiently high price through more collusive behaviour on the part of the leader. Of course, firms could not offer an efficiency rationale for such a royalty rate (the follower would produce under higher marginal costs of production) and a competition authority would ban such a royalty.

[6] This is guaranteed by Assumption 1.

$$q_L = \text{argmax}\, \pi_L^v = \left(a - q_L - q_l(q_L)\right)q_L + d\left(a - q_L - q_l(q_L)\right)q_l(q_L) \tag{6}$$

which yields quantities $q_L = a\,(1-d)/(2-d)$ and $q_l = a/(2(2-d))$ and licensee's profit $\pi_l^v = (1-d)\frac{a^2}{4(2-d)^2}$. The licensor's payoff has two components, namely, their own profit, $\frac{a^2(1-d)}{2(2-d)^2}$, plus a royalty income, $d\frac{a^2}{4(2-d)^2}$, and, as a result, the chosen ad-valorem royalty is:

$$d = \arg\max \frac{a^2}{4(2-d)}, \ \text{s.t: } \pi_l^v \geq \pi_l^n \tag{7}$$

Since the licensor's payoff increases, and the licensee's profit decreases, with ad-valorem royalty *d,* the optimal ad-valorem royalty will be given by the fulfilment of the licensee's participation constraint. Taking into account that the licensee's profit amounts to $\pi_l^v = \frac{a^2(1-d)}{4(2-d)^2}$ if the innovation is accepted, and to $\pi_l^n = \frac{(a-3c)^2}{16}$ if the innovation is refused, then the optimal ad-valorem royalty rate is:

$$d = 2\left(\sqrt{s(1+s)} - s\right), \text{being } s \equiv \left(\frac{a}{a-3c}\right)^2 - 1 \tag{8}$$

where $0 < d < 1$ for all admissible values of parameters *a* and all *c* satisfying Assumption 1. Thus, the licensor's profit amounts to:

$$\pi_L^v = \frac{a^2 + a\sqrt{3c(2a-3c)}}{8} \tag{9}$$

From (4) and (9), the following result holds.

Proposition 1. *If the innovator is the market leader, ad-valorem royalty is the preferred licensing mechanism.*

Proof. According to Eqs. (4) and (9), the difference in licensor's profit using ad-valorem or per-unit royalty is $\pi_L^v - \pi_L^u = \frac{a\sqrt{3c(2a-3c)} - 4c(a-c)}{8}$. This difference is strictly positive for $c > 0$ if $3a^2(2a-3c) > 16c(a-c)^2$ holds. The LHS of this inequality is decreasing in c and achieves its lowest value at $c = a/3$ amounting to $3a^3$, whereas the RHS is increasing in $c \in (0, a/3)$ and achieves its highest value at $c = a/3$ is $64a^3/27$, strictly lower than $3a^3$. Hence $\pi_L^v > \pi_L^u$ for $c \in (0, a/3)$. ■

Both contingent royalties modify profits for the licensor in two ways: there is a change in both their own profit and in the royalty income captured from the licensee. From Eqs. (2) and (6) it follows that ad-valorem royalty compared to per-unit royalty allows the licensor (and, thus, also the licensee) to better adjust production. Hence, the licensor reduces production more under ad-valorem royalty than under per-unit royalty, leading the licensee to increase production more; however, the increase in the latter does not outweigh the reduction in the former, so total production with ad-valorem royalty is lower than with per-unit royalty: this is because ad-valorem royalty licensing exercises a stronger collusive effect. The outcome is reduced profit for the licensor but increased royalty income, thanks to the increase in the price of the good and also in the licensee's production. In sum, a higher royalty income more than compensates for the reduced profitability of the licensor's own operations. This result extends San Martin and Saracho (2010) findings to a Stackelberg setting in which the innovator plays as leader.

3.2 The licensor plays as follower

Assume now that the licensor chooses the quantity to produce after observing the rival's pre-committed quantity. Under per-unit royalty licensing, the licensor chooses the quantity given by:

$$q_L = \arg\max \pi_L^u = (a - q_L - q_l)q_L + rq_l \tag{10}$$

where superscript u stands for per-unit royalty. Solving Eq. (10) affords $q_L(q_l) = (a - q_l)/2$. Note that licensing does not change the strategic interaction between leader and follower; it only affects market outcomes if the royalty is set below the marginal cost with the old technology (and the leader is therefore more efficient). The licensee then chooses to produce:

$$q_l(q_L) = \arg\max \pi_l^u = (a - r - q_L(q_l) - q_l)q_l \tag{11}$$

which yields $q_l = (a - 2r)/2$ and $q_L = (a + 2r)/4$. As a result, the licensor chooses the per-unit royalty rate $r \leq c$ that maximizes the sum of market profit and royalty revenue:

$$\max_r \pi_L^u = \frac{(a+2r)^2}{16} + r\frac{a-2r}{2} \tag{12}$$

yielding $r = c$ (provided that c satisfies Assumption 1). Thus, the licensee is left indifferent between accepting or refusing the innovation (since productions remain unchanged at $r = c$ as compared to a no-licensing context), and the licensor's profit amounts to:

$$\pi_L^u = \frac{a^2+12c(a-c)}{16}, \tag{13}$$

which is strictly larger than the profit without licensing, because, in addition to the same own profit, the licensor can reap the extra revenue rq_L from the licensee.

If, on the other hand, the licensor transfers the innovation through ad-valorem royalty d, it chooses to produce:

$$q_L = \arg\max \pi_L^v = (a - q_L - q_l)q_L + d(a - q_L - q_l)q_l \tag{14}$$

i.e., $q_L(q_l) = (a - (1 + d)q_l)/2$. In the presence of ad-valorem royalty the licensor reduces production since the effect of higher market prices on royalty revenue is internalized. In turn, the licensee chooses the quantity:

$$q_l = \arg\max = \pi_l^v = (1 - d)(a - q_L(q_l) - q_l)q_l \tag{15}$$

which yields $q_l = a/(2(1 - d))$ and, consequently, $q_L(q_l) = a(1 - 3d)/(4(1 - d))$. As result, the firms' profits are $\pi_l^v = a^2/8$ and:

$$\pi_L^v = \frac{a^2(1-3d)}{16(1-d)} + d\frac{a^2}{8(1-d)} = \frac{a^2}{16} \tag{16}$$

for any admissible value $d \in (0, 1/3)$.[7] Strikingly, the licensee benefits strictly from licensing through ad-valorem royalty as compared to per-unit royalty, while the licensor is strictly worse off. The intuition is that ad-valorem royalty revenue cannot compensate for the fact that the licensee's market share is much increased – directly because it is a much more efficient firm (its marginal cost goes from *c* to zero), and indirectly because the licensor cuts production to enhance the licensee's sales (and thus increases their own licensing revenue). This is recorded in the following proposition.

Proposition 2. *If the licensor is the follower, per-unit royalty is the preferred licensing scheme.*

It is noteworthy that the quantity produced by both the licensor and the licensee under per-unit royalty is greater than under ad-valorem royalty; thus, total production under per-unit royalty exceeds production under ad-valorem royalty. In other words, per-unit royalty is a less collusive instrument than ad-valorem royalty. However, according to Proposition 2, the licensor prefers per-unit to ad-valorem royalties. The reason is that licensing income under per-unit royalty does not depend on the price of the good and so, unlike what occurs under ad-valorem royalty, is not affected by the price reduction resulting from increased production. Therefore, the loss in the licensor's own profit with per-unit royalty as compared to ad-valorem royalty is more than offset by the increase in royalty revenue.

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[7] Otherwise, $q_L = 0$.

4. Welfare

Having examined the impact that the licensor's market status has on the licensing scheme, in this section we investigate the welfare impact. To that end, we define aggregate welfare as the non-weighted sum of consumer surplus and firms' profits, i.e.:

$$W = \frac{1}{2}Q^2 + \pi_L + \pi_l, \text{ where } Q = q_L + q_l \tag{17}$$

and the following result holds.

Proposition 3. *As compared to a no-licensing context the diffusion of an innovation:*

(i) *Hurts consumers and society as a whole if the innovation is from the leader firm.*

(ii) *Is innocuous for consumers and benefits society as a whole if the innovation is from the follower firm.*

Proof.

(i) Denote w.l.o.g. the innovator as firm 1 and the rival as firm 2, and assume that the innovator operates as the leader. Without licensing, firm 1 operates at zero marginal cost and produces $q_1^n = (a + c)/2$ (where superscript n denotes no licensing), whereas firm 2 operates at marginal cost c and produces $q_2^n = (a - 3c)/4$. Thus, consumer surplus amounts to $CS^n = (3a - c)^2/32$, industry profits amount to $\pi^n = (3a^2 - 2ac + 11c^2)/16$, and aggregate welfare amounts to $W^n = (15a^2 - 10ac + 23c^2)/32$. In contrast, with licensing (by means of ad-valorem royalty according to Proposition 1), consumer surplus amounts to $CS^v = a^2(3 - 2d)^2/8(2 - d)^2$, industry profits are $\pi^v = a^2(3 - 2d)/4(2 - d)^2$, and total welfare amounts to $W^v = a^2(3 - 2d)(5 - 2d)/8(2 - d)^2$. Comparison of CS^n with CS^v, and W^n with W^v yields the stated result.

(ii) Continuing to denote the innovator as firm 1 and the rival as firm 2, and now assuming that the innovator operates as the follower, production levels are $q_1^n = (a + 2c)/4$ and $q_2^n = (a - 2c)/2$, respectively. In a licensing context, production by both remains unchanged, but the efficiency gain of firm 2, which the licensor can reap through royalties, amounts to c per unit produced and allows the licensor to add $c(a - 2c)/2$ to their own profit. Thus, consumers obtain the same consumer surplus as they would receive under in a no-licensing situation. Aggregate welfare, on the other hand, improves because of the increase in the licensor's profit. ■

As compared to the no-licensing case, the diffusion of an innovation is innocuous for consumers when the innovative firm is the follower, but hurts consumers otherwise. This occurs for the following reason: while licensing through per-unit royalty leaves the licensee with the same cost of production as in the absence of licensing (affording the same quantities as produced for no licensing), ad-valorem royalty leads the market to be more collusive, so consumers must pay a higher price than they would pay if licensing did not hold.

Finally, if we consider society as a whole, the welfare impact of the diffusion of the innovation depends on the status of the innovation holder: diffusion of a leader's innovation is welfare reducing, whereas diffusion of a follower's innovation is welfare increasing. Diffusion of the technology leads to a more efficient industry because both leader and follower firms use the new technology; if consumer surplus is not affected (as is the case when the licensor is the follower), then society as a whole must benefit. But if technology diffusion leads to a more collusive industry, the improvement in production efficiency does not compensate for the negative impact on consumer surplus.

5. Incentives to licensing and disseminating innovations

What sort of innovating firm – leader or follower – has a greater incentive to disseminate an innovation? Our model suggests that the incentive to disseminate a small innovation is stronger for leaders than for followers, whereas the opposite holds if the innovation is large.

Proposition 4. *A cut-off value exists for the size of the innovation,* $c^* = \frac{1}{7}\left(4 + \frac{1}{(2\sqrt{6}-5)^{1/3}} + (2\sqrt{6}-5)^{1/3}\right)a$*, with* $0 < c^* < a/3$*, such that:*

- **i)** *If the size of the innovation,* c*, is sufficiently small, such that* $c < c^*$*, the leader has a greater incentive to license than the follower.*
- **ii)** *If the size of the innovation,* c*, is sufficiently large, such that* $c > c^*$*, the follower has a greater incentive to license than the leader.*

Proof. When a leading innovator licenses the innovation as compared to not licensing it, they obtain an increase in their profit of:

$$\frac{a^2 + a\sqrt{3c(2a-3c)}}{8} - \frac{(a+c)^2}{8} = \frac{a\sqrt{3c(2a-3c)} - 2ac - c^2}{8} \qquad (18)$$

On the other hand, when the follower innovator licenses the innovation as compared to not licensing it, they obtain an increased profit of:

$$\frac{a^2+12c(a-c)}{16}-\frac{(a+2c)^2}{16}=\frac{c(a-2c)}{2} \qquad (19)$$

Comparison of Eqs. (18) and (19) yields the result. ■

Since the licensing mode depends on whether the innovator is the market leader or follower, licensing a small-sized innovation benefits a licensor with leader status more than a licensor with follower status because the former uses ad-valorem royalty as licensing scheme; in contrast, licensing a large-sized innovation yields more profit to a licensor with follower status than to a licensor with leader status because the former uses per-unit royalty.

Finally, concerning the incentives to innovate, the following result can be stated:

Proposition 5. *There is a cut-off value for the size of the innovation,* $c^{**}=\frac{1}{6}\left(4+\frac{1}{\left(3\sqrt{7}-8\right)^{1/3}}+\left(3\sqrt{7}-8\right)^{1/3}\right)a$, *with* $0<c^{**}<a/3$, *such that:*

- **(i)** *If the size of the innovation,* c, *is small, such that* $c<c^{**}$, *the leader has greater incentive to innovate than the follower.*
- **(ii)** *If the size of the innovation,* c, *such that* $c>c^{**}$, *the follower has greater incentive to innovate than the leader.*

Proof. The profit of an innovator that operates as a leader increases as follows:

$$\frac{a^2+a\sqrt{3c(2a-3c)}}{8}-\frac{a^2}{8}=\frac{a\sqrt{3c(2a-3c)}}{8} \qquad (20)$$

when it undertakes R&D and develops the innovation as compared to the situation without the innovation. On the other hand, the profit of an innovator operating as a follower in the product market increases as follows:

$$\frac{a^2+12c(a-c)}{16}-\frac{a^2}{16}=\frac{3c(a-2c)}{4} \qquad (21)$$

when it innovates as compared to the situation when it does not innovate. The result follows from Eqs. (20) and (21). ■

Thus, if we assimilate large firms with those that play as leaders at the marketplace and small firms with those that play as followers, our model suggests that the relationship between firm size and innovation depends on the size of the innovation. For small innovations, the incentive to engage in R&D is greater for large firms, whereas for large innovations, that incentive is greater for small firms. The intuition of this result is as follows: a small innovation can only have a large impact on profit of the innovating firm if it has already a large market share, while a large innovation will have a large effect on the market share of a small firm, but not such a large effect on a firm that already dominates the market.

6. Final remarks

We have shown that an inside licensor with a cost-reducing innovation tends to choose the licensing method that makes the product market more collusive. The licensor's market position therefore affects the choice of licensing method. When the licensor acts as a leader, ad-valorem royalty is preferred, because it leads the market price to be higher than for per-unit royalty. However, when the licensor is a follower, per-unit royalty is preferred as it makes the market more collusive.

Taking into account both the innovator's market status and choice of licensing method, the licensing impact on welfare can be evaluated. Since licensing tends to create a more collusive market, in welfare terms the increase in production efficiency never compensates for the reduction in consumer surplus. As a consequence, only licensing that is innocuous from the consumer point of view can lead to welfare improvement.

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