Licensing a product innovation in a Cournot industry

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10 January 2023

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Abstract

We study how a firm licenses a product improvement innovation to its rival in the final market. Contrary to what happens with fixed-fee licensing or per-unit royalty licensing, pure ad-valorem royalty licensing is optimal but is welfare reducing. On welfare grounds, fixed-fee licensing dominates per-unit royalty agreements, but has the disadvantage that firms sometimes fail to reach an agreement if licensing deals are restricted to feature fixed fees. A simple rule for a second-best optimal policy on technology licensing is proposed.

Keywords: Product innovation, licensing, Cournot competition, welfare

JEL Classification: D43, D45

1. Introduction

Product innovation refers to the development and improvement of products to solve problems for consumers, firms, or society at large. Along with process (cost-reducing) innovation, it is one of the main economic drivers, both for organizations and society at large. As pointed out in empirical research (Petsas and Giannikos, 2005), product innovation is even more common than process innovation in industries like pharmaceuticals, where more than three-quarters of R&D expenditure is dedicated to product innovation.

Significant product innovation is by firms that not only exploit the innovation themselves, but also are simultaneously incentivized to transfer them to direct competitors (Avagyan et al., 2014; Jiang and Shi, 2018). Procter & Gamble, for instance, frequently licenses its manufacturing know-how to direct competitors in the same product market (Parhankangas et al., 2003); Samsung Electronics, HTC Corp. and other Android device manufacturers are direct competitors with Microsoft Corp. in markets such as mobile computing devices and their operating systems, as well as they simultaneously pay Microsoft Corp. a licensing royalty per Android device for some device operating system features (Hoffman, 2014); Tesla Motors in 2014 made its electric vehicle technology patents available to other car makers (Jian and Shi, 2018); Ford Motor Company began licensing, to direct rivals, its industrial property and know-how rights for a passenger-side airbag deactivation switch as far back as 1997, and in 2000, its diesel fuel conditioning module (Fradkin, 2014) and its electric vehicle patents (Arce, 2015). More generally, empirical research confirms this business practice: around 50% of product innovations are commercialized by their owners at the same time as transferred within industries (Zou and Cheng, 2020).[1]

The literature provides the rationale for this business practice, mainly that it discourages potential competitors from producing similar products (Fradkin, 2014), promotes economies of scale (Fradkin, 2014), alleviates competition, and reaps the innovation return, especially in certain product life cycle phases (Abernathy and Utterback, 1978; Melumad and Ziv, 2004; Jiang and Shi, 2018).

The terms of licensing contracts is typically private information between the involved firms, and so it is not easy to know the contractual details. Nonetheless, the literature shows that,

[1] Along the same lines, a McKinsey survey shows that around 25% of total revenue and profits across industries come from the launch of new products. See https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/how-to-make-sure-your-next-product-or-service-launch-drives-growth

among a wide range of different payment schemes,[2] royalty licensing, and particularly profit-sharing licensing, seem to be a frequent means of transferring product innovations.

The theoretical literature on how to license a product innovation contains results for when the innovation owner also operates in the product market. For example, Lin and Kulatilaka (2006) showed that an inside innovator in a Cournot duopoly with a quality-improving innovation that exhibits network effects prefers fixed-fee licensing if network effects are strong, but a royalty rate, either alone or in combination with a fee for less intense network effects. Li and Song (2009) explored the interaction between two firms when one firm can transfer either its latest or an obsolescent technology to a Cournot competitor producing a lower quality good; they showed that, irrespective of the type of contract, licensing the new product is always superior to licensing the obsolescent product. Yan et al. (2012) investigated, in a Bertrand duopoly, when and how one of the firms licenses its product innovation to its rival. Zou and Cheng (2020) studied a vertically differentiated Cournot oligopoly in which one of the firms owns a top quality product, showing that, under non-exclusive licensing (per-unit or ad-valorem) royalty licensing is optimal for the licensor if the quality difference between products is small. However, under exclusive licensing, a two-part tariff (2PT) contract is optimal. Moreover, if fixed-fee licensing is feasible, the licensor favours exclusive licensing.

Our model contributes to the licensing literature by considering a Cournot duopoly in which one firm owns a high-quality good (product innovation) and competes with a rival producing a lower-quality good. The aim is to investigate whether or the innovative firm licenses its innovation, what the optimal licensing contract could be, and the licensing impact on consumers and society as a whole. A Cournot setting fits this analysis reasonably well, especially for industries where production capacity is important, i.e., industries with factories,[3] and where the innovation transfer is complete rather than partial (see Creane and Konishi, 2009).

In this setup, we first show that if royalties are not feasible and only a fixed-fee payment can be contemplated for the license agreement, then the innovation may be not transferred. In particular, when the quality improvement is sufficiently large, the licensor prefers not to transfer the innovation, since without licensing the situation is quasi-monopolistic, whereas a licence would increase competition in the product market.

We also show that if royalties are feasible in licensing deals, firms can always find a licensing agreement that suits both the licensor and the licensee. The optimal licensing deal in this case consists of a pure ad-valorem (or profit-sharing) royalty. Profit-sharing through the royalty has an anticompetitive effect that leads to a reduction in industry output, and, even though the quality

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[2] See the many examples described in Kulatilaka and Lin (2006) and Niu (2017).

[3] Otherwise, the market interaction would be more in line with price competition.

of the licensee' product is increased, the overall effect is a reduction in consumer surplus and in aggregate welfare.

We further show that a licensing agreement involving a per-unit royalty also increases the profits of both firms, but is a less collusive device than if an ad-valorem royalty were used. This licensing agreement increases both consumer surplus and aggregate welfare. Thus, intervening in product innovation licensing by requiring that no royalty can be specified in a licensing deal may sometimes be an appropriate measure to avoid output contraction and protect the interests of consumers, and particularly when the product innovation is small. However, if the quality improvement is large, the regulator should ban ad-valorem royalties, but allow the use of per-unit royalties.

The remainder of the paper is structured as follows. Section 2 describes the model. Section 3 contains analyses of the game when licensing is based on a fixed-fee payment (subsection 3.2), when licensing is based on a fixed-fee payment combined with a per-unit royalty (subsection 3.3), or when licensing is based on a fixed-fee payment plus a royalty on revenues or profits (subsection 3.4). Section 4 investigates the welfare impact of licensing. Finally, Section 5 concludes.

2. The model

We consider a Cournot duopoly, where Firm 1 produces a high-quality good $q_1 = 1$, whereas Firm 2 produces a low-quality good $q_2 = t$, $0 < t < 1$. The lower the parameter t, the greater the quality difference between the goods. Consumers are distributed in the interval [0, 1] and patronize, at most, one unit of the quality-differentiated product i at price p_i, $i = 1, 2$. Thus, each customer i is willing to pay θq_i for a good of quality q_i and his or her net utility amounts to $U_i = \theta q_i - p_i$, where $0 \leq \theta \leq 1$ is a taste parameter that measures how the quality is valued. The customer who is indifferent between purchasing product 1 (the high-quality product) or product 2 (the low-quality product) is defined by the condition $\theta q_1 - p_1 = \theta q_2 - p_2$, which leads to $\theta^* = \frac{p_1 - p_2}{1-t}$. On the other hand, no customer will purchase any product when U_2, the net utility derived from consumption of low-quality product, is below zero; hence, $\theta q_2 - p_2 \geq 0$ is necessary for the product to be bought. Thus, customers in the interval $[0, \underline{\theta}]$ with $\underline{\theta} \equiv \frac{p_2}{t}$ do not purchase any product, customers in the interval $[\underline{\theta}, \theta^*]$ purchase Firm 2's product, and consumers in the interval $[\theta^*, 1]$ purchase Firm 1's product. From here, it follows that

$$x_1 = \int_{\theta^*}^{1} d\theta = 1 - \theta^* = 1 - \frac{p_1 - p_2}{1-t} \quad (1)$$

and

$$x_2 = \int_{\underline{\theta}}^{\theta^*} d\theta = \theta^* - \underline{\theta} = \frac{p_1 - p_2}{1-t} - \frac{p_2}{t} \tag{2}$$

are the Firm 1 and 2 demand functions of products, respectively, from which, therefore,

$$p_1 = 1 - x_1 - tx_2 \tag{3}$$

and

$$p_2 = t(1 - x_1 - x_2) \tag{4}$$

are the respective inverse demands when Firm 1 does not license its product innovation to Firm 2. The firms' marginal costs are normalized to zero.

The licensing game is as follows. In the first stage, Firm 1, the product innovation's owner, decides whether to license it to Firm 2. In the case of a licensing agreement, the contract between Firms 1 and 2 may consist of a fixed-fee payment alone or a fixed fee combined with a royalty that, in turn, may be either based on Firm 2's production (a per-unit royalty) or Firm 2's revenue (an ad-valorem royalty).[4] In the second stage, irrespective of whether or not there is an agreement, both firms simultaneously decide their levels of production.

3. Game analysis

3.1 No licensing

When the quality-improved product is not licensed, the firms' inverse demands are those given in Eqs. (3)-(4), from which equilibrium output levels are[5] $x_1^n(t) = \frac{2-t}{4-t}$ and $x_2^n(t) = \frac{1}{4-t}$, while equilibrium prices are $p_1^n(t) = \frac{2-t}{4-t}$ and $p_2^n(t) = \frac{t}{4-t}$. Thus, Firm 1's and 2's profits under no licensing are, respectively, $\pi_1^n(t) = \frac{(2-t)^2}{(4-t)^2}$ and $\pi_2^n(t) = \frac{t}{(4-t)^2}$, leading to industry profits of $\pi^n(t) = \frac{4-3t+t^2}{(4-t)^2}$, aggregate consumer surplus of $CS^n(p_1^n(t), p_2^n(t)) = \int_{\theta^*}^{1}(\theta - p_1^n)d\theta + \int_{\underline{\theta}}^{\theta^*}(t\theta - p_2^n)d\theta = \frac{4+t-t^2}{2(4-t)^2}$, and aggregate welfare of $W^n(t) = \frac{12-5t+t^2}{2(4-t)^2}$.

3.2 Fixed-fee licensing

In contrast, if, in the first stage, Firm 1 licenses the innovation by means of a fixed-fee contract f and Firm 2 accepts it in the second stage, then they face the same inverse demand $p_i = 1 - x_1 -$

[4] In our set up ad-valorem royalty is equivalent to profit-sharing royalty since there are not production costs.

[5] Throughout the article, superscript n in equilibrium profits, quantities, etc. denotes no licensing while other subscripts denote as follows: licensing through a fixed-fee payment (f), through a 2PT contract involving a per-unit royalty (u) and through a 2PT featuring an ad-valorem royalty (v).

x_2, $i = 1, 2$. From Cournot competition, both firms choose, in the last stage of the game, the quantity $x_1^f = x_2^f = \frac{1}{3}$, and the equilibrium price is $p^f = \frac{1}{3}$, while their profits amount to $\pi_1^f = \pi_2^f = \frac{1}{9}$ and, as result, industry profit is $\pi^f = \frac{2}{9}$. Licensing by means of a fixed-fee payment is thus profitable for the industry only when $\pi^f > \pi^n(t)$, which is the case only if $\frac{4}{7} < t < 1$.[6] The explanation is as follows. In terms of impact on industry profits, licensing involves two opposing forces: an efficiency effect and a competition effect. The former reflects the increase in industry efficiency, as Firm 2 sells an improved product under the license, and therefore, all else being equal, increases industry profits. The latter reflects the increase in competition, since Firm 2's product becomes a better alternative to Firm's 1 product, thereby reducing industry profits. The competition effect predominates when $1 - t$, the difference in original qualities, is large, namely when $0 \le t < \frac{4}{7}$, and industry profits decrease, because Firm 1, a quasi-monopolist without licensing, with licensing would have a worthy rival, reflected in reduced overall industry profits. In contrast, if the quality improvement of the innovation is small, as $\frac{4}{7} \le t \le 1$, without licensing the rival is a worthy alternative for consumers and so the market is competitive, with the result that the efficiency effect predominates.

We can summarize this result as follows.

Lemma 1. *Under fixed-fee licensing the following hold:*

a) *If the quality of the innovation is $t \in \left[0, \frac{4}{7}\right)$, Firm 1 does not license it.*

b) *If the quality of the innovation is $t \in \left[\frac{4}{7}, 1\right]$, Firm 1 licenses it by means of a fixed-fee payment $f(t)$ that satisfies $\underline{f}(t) < f(t) < \overline{f}(t)$, where $\underline{f}(t) \equiv \pi_1^n(t) - \pi_1^f = \frac{4(1-t)(5-2t)}{9(4-t)^2}$ and $\overline{f}(t) \equiv \pi_2^f - \pi_2^n(t) = \frac{(1-t)(16-t)}{9(4-t)^2}$.*

Note that under a fixed-fee licensing agreement, the consumer surplus amounts to $CS^f = \frac{2}{9}$, which is larger than that without licensing for any difference in quality level,[7] and overall aggregate

[6] The licensing agreement is accepted by firms if both must end up with higher profits. For Firm 2 to accept the licensing agreement, the fixed-fee payment f must satisfy $\pi_2^f - f \ge \pi_2^n(t)$, or $f \le \overline{f}(t) \equiv \pi_2^f - \pi_2^n(t)$, while Firm 1 is willing to license the innovation if $\pi_1^f + f \ge \pi_1^n(t)$ or $f \ge \underline{f}(t) \equiv \pi_1^n(t) - \pi_1^f > 0$. Only when $4/7 < t < 1$ do we have $\underline{f}(t) < \overline{f}(t)$, making it thus feasible for fixed fees to be satisfactory to both firms.

[7] There are winners and losers among consumers under fixed-fee licensing. Consumers with a high valuation for the product are better off, since they end up paying a lower price for the high quality product, $p^f < p_1^n(t)$, while consumers with a low valuation for the product that buy the low-quality product with no licensing are left out of the market under licensing, since $\underline{\theta} = \frac{p_1^n(t)}{t} < p^f$.

welfare, defined as $W^f = \pi^f + CS^f$, is $W^f = \frac{4}{9}$, which is also larger that that without licensing. Therefore, fixed-fee licensing is valuable for society for any difference in quality level.

3.3 Licensing by means of a 2PT contract involving per-unit royalties

If licensing occurs by means of a 2PT contract (f, r) consisting of a fixed-fee payment f combined with a royalty r per unit of Firm 2's output, then the profit functions of Firms 1 and 2 are $\pi_1^u = (1 - x_1 - x_2)x_1 + rx_2$ and $\pi_2^u = (1 - r - x_1 - x_2)x_2$, respectively. From here, the equilibrium quantities in the third stage are $x_1^u(r) = \frac{1+r}{3}$ and $x_2^u(r) = \frac{1-2r}{3}$, respectively, and $\pi_1^u(r) = \frac{(1+r)^2}{9} + \frac{r(1-2r)}{3}$ and $\pi_2^u(r) = \frac{(1-2r)^2}{9}$ are the corresponding equilibrium profits. Note that Firm 1's profit increases with per-unit royalty r, and satisfies $\pi_1^u(r) > \pi_1^n(t)$ as long as $r > \underline{r}(t) \equiv \frac{1}{2} - \frac{3\sqrt{5t(8-3t)}}{10(4-t)}$, whereas Firm 2's profit decreases with per-unit royalty r, and satisfies $\pi_2^u(r) > \pi_2^n(t)$ as long as $r < \overline{r}(t) \equiv \frac{1}{2} - \frac{3\sqrt{t}}{2(4-t)}$, where $\underline{r} < \overline{r}$ for all $0 < t < 1$.[8] Moreover, overall profits, $\pi_1^u(r) + \pi_2^u(r) = \frac{2+r(1-r)}{9}$, increase with per-unit royalty r and are greater than $\pi_1^n(t) + \pi_2^n(t) = \frac{(2-t)^2+t}{(4-t)^2}$, i.e., the join profits under no licensing, whenever $r > r_{\min}(t) \equiv \max\left\{0, \frac{1}{2} - \frac{3\sqrt{t(4-3t)}}{2(4-t)}\right\}$.[9]

Since $r_{\min}(t) < \underline{r}(t)$, both firms can agree on a per-unit royalty r, $\underline{r}(t) < r < \overline{r}(t)$, that increases the profits of both. Thus, the optimal contract *will not feature a fixed fee*: if they were to settle on a contract (f_a, r_a) with $f_a > 0$ satisfying $\pi_2^u(r_a) - f_a \geq \pi_2^n(t)$, since joint profits are increasing with the per-unit royalty, there would be an alternative contract with $r_b > r_a$ and a lower fixed fee $f_b \geq 0$, $f_b < f_a$, that would satisfy $\pi_2^u(r_b) - f_b = \pi_2^u(r_a) - f_a$ and $\pi_1^u(r_b) + f_b > \pi_1^u(r_a) + f_a$.

Therefore, if per-unit royalties are allowed in licensing deals, firms can set a licensing agreement that benefits both parties, with the contract featuring the highest per-unit royalty r^* that Firm 2 is willing to accept, and with no fixed fee;[10] as long as $t > 0$ there will be no monopolization of the

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[8] Note that at $t = 0$ we have $\underline{r}(0) = \overline{r}(0) = \frac{1}{2}$, the per-unit royalty that leads to monopoly; and at $t = 1$ we have $\underline{r}(1) = \overline{r}(1) = 0$, the per-unit royalty that leads to the Cournot outcome.

[9] Note also that $r_{\min}(t) = 0$ if $\frac{4}{7} < t < 1$. Recall that these are the values of the quality difference for which Cournot profits are larger than with no licensing.

[10] If legal, Firm 1 *would pay a fixed fee* to Firm 2 in exchange of setting $r = 1/2$ in order to monopolize the industry; this contract would lead Firm 2 to stop operations and would be equivalent to Firm 1 acquiring Firm 2. Of course, a regulator must ban such a contract, since it would reduce both consumer surplus and aggregate welfare when compared to a licensing agreement without fixed fees.

industry since $r^*(t) < \overline{r}(0) = \frac{1}{2}$. The royalty rate decreases with the licensee's bargaining power and, consequently, collusion is softened when Firm 2 has more bargaining power. Finally, when Firm 1 licenses its product innovation by means of a pure per-unit royalty contract r, the consumer surplus is $CS^u(r) = \frac{(2-r)^2}{18}$.

From here, we can state the following result.

Lemma 2. *When the licensing deal involves a per-unit royalty r, the following hold:*

a) *Both firms can increase their profits through a licence featuring a royalty rate that satisfies* $\underline{r}(t) < r < \overline{r}(t)$.
b) *As compared to a no-licensing context, aggregate consumer surplus increases.*

Proof. The first statement in Lemma 2 has already been proved in the main text. On the other hand, consumer surplus without a licence amounts to $CS^n = \frac{4+t(1-t)}{2(4-t)^2}$, whereas licensing by means of a per-unit royalty contract leads the industry to become more collusive as the royalty rate increases. Therefore, the worst-case scenario for consumers is $r = \overline{r}(t)$, which yields consumer surplus $CS^u(\overline{r}(t)) = \frac{16-7t+t^2+2(4-t)\sqrt{t}}{8(4-t)^2}$. It is easy to verify that $CS^u(\overline{r}(t)) > CS^n$ for all $0 < t < 1$. ■

3.4 Licensing by means of a 2PT contract involving ad-valorem royalties

Assume now that Firm 1 licenses its innovation by means of a 2PT contract as (f, d), where d, $0 < d < 1$, is an ad-valorem royalty; in our case, this is equivalent to a profit-sharing royalty. In this case, Firm 1 produces

$$x_1^v = \text{argmax}_{x_1}\, \pi_1^v = (1 - x_1 - x_2)x_1 + d(1 - x_1 - x_2)x_2 \tag{6}$$

and Firm 2 produces

$$x_2^v = \text{argmax}_{x_2}\, \pi_2^v = (1 - d)(1 - x_1 - x_2)x_2 \tag{7}$$

This leads to $x_1^v(d) = \frac{1-d}{3-d}$ and $x_2^v(d) = \frac{1}{3-d}$ and, consequently, $\pi_1^v(d) = \frac{1}{(3-d)^2}$ and $\pi_2^v(d) = \frac{1-d}{(3-d)^2}$ are firms' profits. Note that Firm 1's profits increase with ad-valorem royalty d, and satisfy $\pi_1^v(d) > \pi_1^n(t)$ as long as $d > \underline{d}(t) \equiv \frac{2(1-t)}{2-t}$; in contrast, Firm 2's profits decrease with ad-valorem royalty d, and satisfy $\pi_2^v(d) > \pi_2^n(t)$ as long as $d < \overline{d}(t) \equiv$

$\frac{(4-t)\sqrt{16-16t+t^2}-(16-14t+t^2)}{2t}$, with $\underline{d} < \overline{d}$ if $0 < t < 1$.[11] Finally, joint profits $\pi_1^v(d) + \pi_2^v(d) = \frac{2-d}{(3-d)^2}$ are increasing in d, and greater than $\pi_1^n(t) + \pi_2^n(t) = \frac{(2-t)^2+t}{(4-t)^2}$, the joint profits without licensing, whenever the ad-valorem royalty satisfies $d > d_{\min}(t) \equiv \max\left\{0, \frac{8-10t+5t^2-(4-t)\sqrt{t(4-3t)}}{2(16-7t+t^2)}\right\}$.[12]

Since $d_{\min}(t) < \underline{d}(t)$, firms can agree on an ad-valorem royalty $d \in \left(\underline{d}(t), \overline{d}(t)\right)$ that increases their profits. The optimal contract, thus, as in the per-unit royalty case, *will not feature a fixed fee*: if they were to settle on a contract (f_a, d_a) with $f_a > 0$ satisfying $\pi_2^v(d_a) - f_a \geq \pi_2^n(t)$, then, since joint profits are increasing in the royalty rate, there would be an alternative contract with a higher royalty rate d_b, $d_b > d_a$, and a lower fixed fee f_b, $0 \leq f_b < f_a$, that would satisfy $\pi_2^v(d_b) - f_b = \pi_2^v(d_a) - f_a$ and $\pi_1^v(d_b) + f_b > \pi_1^v(d_a) + f_a$.

Therefore, the optimal contract will feature the highest ad-valorem royalty d^* that Firm 2 is willing to accept, with no fixed-fee payment; and as long as $t > 0$ there will be no monopolization of the industry since $d^* < \overline{d}(0) = 1$. That is, irrespective of the bargaining power of the firms involved in the agreement, in no case does the licensing contract feature a fixed payment when ad-valorem royalties are feasible. A fixed-fee payment in combination with an ad-valorem royalty (as in a 2PT contract) would decrease the royalty rate and would therefore reduce collusion in the marketplace, which would reduce industry profits. Thus, the licensing agreement that the firms choose degenerates into a pure ad-valorem (or profit-sharing) royalty.

If we compare industry profits and consumer surplus under per-unit and ad-valorem royalties, the following lemma can be stated.

Lemma 3. *For any (pure) ad-valorem royalty licensing contract d, $\underline{d}(t) < d < \overline{d}(t)$, there is an equivalent (pure) per-unit royalty licensing contract $r^e(d) = \frac{d}{3-d}$, such that $\underline{r}(t) < r^e(d) < \overline{r}(t)$, which leads to the same joint profits and the same consumer surplus.*

However, when we look at firm's individual profits, we have $\pi_2^u\left(r^e(d)\right) < \pi_2^v(d)$. So, to ensure a given level of profits for Firm 2, both firms must agree to a lower per-unit royalty r; in other words, firms cannot sustain the same level of collusion under per-unit as under ad-valorem royalty

[11] Note that at $t = 0$ we have $\underline{d}(0) = \overline{d}(0) = 1$, the ad-valorem royalty that leads to monopoly outcome, and at $t = 1$ we have $\underline{d}(1) = \overline{d}(1) = 0$, which leads to the Cournot outcome.

[12] As in the case of per-unit royalties, $d_{\min}(t) = 0$ if $\frac{4}{7} < t < 1$. Recall that these are the values of the quality improvement to the innovation for which firms' profits under licensing are larger than under no licensing.

licensing. Consequently, firms prefer an ad-valorem royalty licensing agreement. Of course, this goes against the interest of consumers, who end up with a lower surplus under ad-valorem than under per-unit royalties. In fact, we can even state the following lemma.

Lemma 4. *As compared to a no-licensing context, (pure) ad-valorem royalty licensing decreases aggregate consumer surplus.*

Proof. When licensing does not occur, the consumer surplus is $CS^n(t) = \frac{4+t(1-t)}{2(4-t)^2}$, whereas with ad-valorem royalty licensing, the industry becomes more collusive as the ad-valorem royalty rate increases. Therefore, the best-case scenario for consumers in a licensing context is $d = \underline{d}(t)$, under which the consumer surplus amounts to $CS^v\big(\underline{d}(t)\big) = \frac{2}{(4-t)^2}$. It is easy to verify that $CS^v\big(\underline{d}(t)\big) < CS^n(t)$ for every $0 < t < 1$. ■

4. The optimal regulation of licensing agreements

It is evident from Lemmas 1-4 that there are conflicting interests between firms and society as a whole: firms prefer the innovation is licensed by means of ad-valorem royalties, but these decrease both consumer surplus and aggregate welfare when compared with a no-licensing scenario. On the other hand, both fixed fees and per-unit royalties increase consumer surplus and aggregate welfare. The regulator prefers fixed fees to per-unit royalties, however, since the former are pro-competitive, whereas firms prefer per-unit royalties to fixed fees, and sometimes (particularly, when the size of the innovation is sufficiently large), the improvement is not transferred if only fixed fees are available.

From this, we can state the following result regarding the impact of an optimal regulatory policy on technology licensing when a welfare-seeking regulator observes the value of parameter t that measures the quality difference in the firms' product, but does not intervene in market competition, cannot force a firm to sign a licensing agreement that reduces its profits, and does not contemplate subsidizing firms.

Proposition 1. *The second-best optimal policy for technology licensing is as follows:*

i) Allow licensing agreements that involve a fixed-fee payment from the licensee to the licensor.

ii) Allow per-unit royalties in licensing agreements if $0 < t < \frac{4}{7}$*, but ban them otherwise.*

iii) Ban any ad-valorem royalties in licensing agreements for all $0 < t < 1$*, as well as any fixed-fee payment from the licensor to the licensee.*

Banning ad-valorem royalties in licensing contracts, irrespective of the size of quality improvement of the innovation, would prevent the industry from becoming collusive. Regarding per-unit royalties, they should be allowed for innovations reflecting a significant quality improvement, as $0 < t < 4/7$; they otherwise would not be transferred, and we know from Lemma 2 that per-unit royalties would improve both consumer surplus and overall industry profits as compared to a no-licensing scenario. However, for innovations reflecting a small quality improvement, i.e., $4/7 < t < 1$, although per-unit royalties would likewise benefit both consumers and industry surplus, these innovations would also be licensed even if the only feasible licensing contract were fixed-fee payments by the licensee. We know that licensing in this way increases the consumer surplus (since market competition is not reduced as with per-unit royalties) and also overall welfare. In sum, licensing deals based on per-unit royalty contracts would benefit consumers and society as a whole as compared to a non-licensing context, whereas prohibiting royalty contracts would lead the licensor to resort to fixed-fee payments, which would be welfare enhancing if the innovation degree is significant.

5. Conclusions

We have studied how a Cournot firm prefers to license a product innovation to its direct competitor by means of a pure ad-valorem royalty (profit-sharing) contract rather than through another way, because it is the device that most increases industry profits as compared to a no-licensing scenario. However, licensing this way is welfare reducing. Thus, depending on the size of quality improvement to the product, an optimal technology transfer policy should restrict licensing royalties to per-unit royalties or even to ban them and only allow fixed-fee payments in licensing deals.

Acknowledgements

The authors acknowledge financial aid from a Xunta de Galicia grant (Consolidación e Estruturación – 2019 GRC GI-2060) and from a Spanish Ministry of Science and Innovation grant (ECO2017-86305-C4-1-R).

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