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Why some product innovations are licensed and others are not?

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ABSTRACT

We study in a Stackelberg industry the licensing of a product that embodies an innovation (quality-improving product) whose owner may be the firm that plays as a leader or a follower in setting output in the the product market. We find that the innovation is transferred (and social welfare is reduced) if its owner is the market-leader firm. However, if the innovation is in the hands of the market-follower firm, it is not licensed, even though licensing would be welfare enhancing. Thus, subsidizing R&D with the mandatory licensing of the resulting innovation may be a socially desirable policy.

1. Introduction

Firms that develop and patent their innovations not only exploit them themselves, but also often transfer them to direct competitors (Jian and Shi, 2018). Instead of commercializing their innovations alone, many innovative firms can also license them to other firms in the same industry (Avagyan et al., 2014). For example, Monsanto does both things with YieldGard Corn Borer and YieldGard Corn Rootworm - two products that developed and patented to protect from two kinds of corn pests - since it not only produces and sells both products, but also has made their production available to Pioneer, which has incorporated them into its corn hybrids (Fulton and Yianaka, 2007).

Among the various ways of transferring an innovation, licensing has gained significant attention in the literature and in practice as an important tool in the managing strategy of many industries. The global licensing market was estimated to be worth USD200 billion in 2011 (Alvarez and López, 2015) and licensing royalty payments grew at a rate of almost 10% between 1990 and 2003 (Athreye and Cantwell, 2007). The empirical evidence reveals that most of the innovations are product innovations (Chang and Peng, 2013), and that more than 50% of licensing deals concerning such innovations are applied within industries (Zou and Cheng, 2020). In addition, the use of royalties is widely observed in licensing by inside licensors. As an example, in 1998, Eli Lilly licensed the rights of the anticancer drug Ontak to Ligand Pharmaceuticals by charging royalties. Likewise, in 2004, Accentia Biopharmaceuticals also licensed the chronic sinusitis product BioNasal from Bio Delivery Science International (BDSI) by paying a royalty rate of 14% on net profit. In this case, to recover BDSI's investment loss, BDSI agreed with Accentia Biopharmaceuticals to pay a USD2.5 million lump fee and to reduce the royalty rate to 7% (Kulatilaka and Lin, 2006). A third example is Arm, the British semiconductor and software design company, that trades its intellectual property as follows: "For a fee, anyone can license one of its off-the-shelf designs, tweak it if

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necessary and sell the resulting chip. Besides licensing revenue, Arm takes a small royalty from every sale of a chip built with its technology".[1]

However, at the same time that licensing is common practice in which inventions are financed and commercialized, is also notorious that many firms have difficulty to find licensing partners (Kani and Motohashi, 2012; Zuniga and Guellec, 2008) and that a significant number of patented innovations held by firms remain unlicensed (Gambardella et al., 2007; Avagyan et al., 2014) and therefore marketed solely by them.

The literature has tried to justify why some patents are licensed, while others are not, and the results are mixed. Small licensors (Gambardella et al., 2007) and both small and large licensors (Zuniga and Guellec, 2008) seem to be more likely to license their innovations. The licensing rate is also positively related to very small and very large licensors (Motohashi, 2008), as well as current patent stock and past history in licensing (Kim and Vonortas 2006b), and negatively related to large market shares (Fosfuri 2006) and the disclosure of too much or too little information (Wuyts and Dutta, 2008). More recently, Avagyan et al. (2014) find that a weak intellectual property right protection can easily diminish the financial attractiveness of licensing, whereas Ruckman and McCarthy (2017) argue that the licensor's standing and organizational learning influence the success of outward licensing rather than the quality of its patent alone.

Our paper makes a theoretical contribution to this debate by using a simple Stackelberg model. We consider a quality-improving innovation held by a firm that plays as a leader in setting the output level in the product market or by a firm that plays as a follower. This reflects the fact that neither does anything prevent the innovative firm from being in a leader or follower position when committing the production level. By way of example, in the semiconductor industry, AMD is a small company that plays as a follower in the semiconductor industry, with both AMD and Intel (the leader firm in such industry) extensively cross-licensing each other's technologies, so that both end up offering products of similar quality. In contrast, both Procter & Gamble and Ford play as leaders in their respective industries and also frequently license their innovations to competitors that play as followers (Jiang and Shi, 2018).

Our simple model then provides a realistic yet tractable description of a licensor that may play one role or another in the marketplace, and allows us to investigate to what extent the market position of the firms involved in the license arrangement has an impact on the decision to license or not and, in the case of licensing, on the contract used and on the effect of that contract on consumers and society as a whole. The model also allows to extend the literature that explores licensing of quality-improving innovations (demand-enhancing innovations) under Cournot competition (Li and Song, 2009; Chang and Peng, 2013; Zou and Cheng, 2020; Neelanjan et al., 2021).[2] Li and Song (2009), studying the interaction between two firms, where one of them has an option to transfer either the latest or the obsolescent technology, show that licensing the new technology is always superior to licensing the obsolescent technology. Chang and Peng (2013), studying the optimal licensing contract for a product innovation in a vertically differentiated duopoly, find that if the marginal cost of the high-quality firm is relatively high (low), fixed-fee licensing is superior (inferior) to royalty licensing for the licensor. Zou and Cheng (2020) have studied product innovation (quality-enhancing) licensing in a vertically differentiated Cournot oligopoly where a quality-leading firm plays as an internal licensor. They show that, under a non-exclusive licensing, the licensor prefers pure royalty licensing if the quality difference between products is small, whereas, a two-part tariff (2PT) is optimal under exclusive licensing. Finally, Neelanjan et al. (2021) discuss licensing between Cournot duopolistic firms in the presence of horizontal and vertical product differentiation, finding that the innovation is licensed from the firm that produces the higher quality product to that which produces the lower quality product, through a fixed-fee payment if both the quality difference (net of cost) and the horizontal differentiation between the two products are relatively low, but through royalty, otherwise.

To this literature we add three findings when the licensor can be either the leader or the follower firm in the product market. First, if the innovation is owned by the leader firm, licensing takes place through a contract consisting solely of an ad-valorem royalty. This contract is preferred over a fixed-fee contract or a contract that features a per-unit royalty, because it is the device that most increases industry collusion. Second, if the innovation belongs to the market follower, it is not licensed, because licensing does not create economic value for it (licensing by means of a fixed-fee payment or by means of ad-valorem royalties would reduce the licensor's profit, whereas licensing by a 2PT contract involving per-unit royalties would leave profit unchanged). Thus, an innovation in the hands of a follower firm would be retained solely by its owner and not licensed to other firms. Third, licensing a product innovation to a competitor that plays as a market follower is anticompetitive and thus harms consumers more than it increases industry profits. Thus, considering that the literature suggests that a well-targeted subsidy can play a key role in mass adoption of a technology (Liao and Sen, 2005), and so help overcome initial confidence barriers, leverage economies of scale, etc., our model adds an additional rationale for policy interventions in technological diffusion: The use of fixed subsidies can promote the diffusion of a product innovation owned by a (small) market-follower firm, as, in the absence of the subsidy, this firm would not license the innovation. Subsidization becomes then a socially desirable policy.

The rest of the paper is structured as follows. Section 2 describes the model, Sections 3 and 4 determine the optimal contract when the licensor is the market leader and the market follower, respectively, Section 5 discusses the welfare impact of licensing, and Section 6 concludes.

[1] https://www.economist.com/business/2022/06/22/why-everyone-wants-arm.

[2] In a Bertrand duopoly model, Yan et al. (2012) conclude that if the licensing contract consists of a fixed payment, then the innovation remains unlicensed, whereas under royalty licensing, the innovation is (is not) licensed if its size is small (large). Likewise, Fang et al. (2015) consider exclusive and non-exclusive licensing by an outside innovator that owns a product innovation, which may create differentiation between the products of two downstream firms that compete in price.

2. The model

We consider a market in which an innovative firm (Firm 1) produces a (quality-enhanced) good of quality $q_1 = 1$ and competes with a rival (Firm 2) that produces a good of lower quality $q_2 = t$, $0 < t < 1$. Thus, parameter t measures the intensity of the innovation, and the lower t, the greater the quality difference between the products of both firms. In this market, each consumer is willing to pay θq_i for a product of quality q_i, and its net utility amounts to $U_i = \theta q_i - p_i$, where p_i is the price of Firm i's product, $i = 1, 2$, and $0 \leq \theta \leq 1$ measures how the consumer values the quality (indicating the consumer type). The consumer who is indifferent between purchasing the higher- or lower-quality product is given by condition $U_1 = U_2$, i.e., $\theta q_1 - p_1 = \theta q_2 - p_2$, which leads to $\theta^* = \frac{p_1 - p_2}{1-t}$. On the other hand, no consumer will purchase any product when the utility provided by the lower-quality product is $U_2 = 0$, i.e., $\theta q_2 = p_2$, which leads to $\underline{\theta} = \frac{p_2}{t}$. Thus, consumers in the interval $[\theta^*, 1]$ will purchase Firm 1′s product, while consumers in the interval $[\theta^*, 1]$ will purchase Firm 2′s product. From here, we obtain $x_1 = \int_{\theta^*}^{1} d\theta = 1 - \theta^* = 1 - \frac{p_1 - p_2}{1-t}$ and $x_2 = \int_{\underline{\theta}}^{\theta^*} d\theta = \theta^* - \underline{\theta} = \frac{p_1 - p_2}{1-t} - \frac{p_2}{t}$, which allow us to define the firms' residual demands as follows:

$$p_1 = 1 - x_1 - tx_2 \text{ and } p_2 = t(1 - x_1 - x_2) \quad (1)$$

We also assume that firms produce, at no cost, the goods that they deliver to the consumers, and that Firm 1 (the licensor) can play as the leader or follower in setting output in the product market. Finally, we consider that the licensing deal may consist of one of the following contracts: first, a fixed-fee-based licence, in which the payment charged to the licensee does not depend on the quantity it will sell in the market; second, a licence that combines a fixed payment and a per-unit royalty for the quantity sold; and third, a license that combines a fixed payment and an ad-valorem royalty as a percentage of the licensee's revenue.[3]

The analysis follows a four-stage non-cooperative game. In the first stage, the innovative firm, either the market leader or the market follower, decides whether or not to license the product innovation to its rival and, in the case of licensing, offers the corresponding contract. In the second stage, the licensee, either the follower or the leader in the marketplace, accepts or refuses the licensor's offer. If accepted, then, in the third stage, the leader − the licensor or the licensee, as the case may be − chooses its output level. Finally, in the fourth stage, the follower − the licensee or the licensor, as the case may be − observes the leader's output − the licensor or the licensee, as the case may be − and decides its own output. As usual, we look for a subgame Nash perfect equilibrium for this licensing game.

3. Game analysis when the patent owner is the market-leader firm

3.1. Licensing by means of a fixed-fee payment

When Firm 1 does not transfer the innovation, then the Stackelberg equilibrium leads to $x_1^n = \frac{1}{2}$ and $x_2^n = \frac{1}{4}$ as the respective quantities, and $\pi_1^n = \frac{2-t}{8}$ and $\pi_2^n = \frac{t}{16}$ as the respective profits.[4] Thus, $\pi^n(t) = \frac{4-t}{16}$ is the total industry profit. These values define the conditions under which Firm 1 prefers or does not prefer to license, and for Firm 2 to accept or reject the licensing contract.

From here, if the licensing contract consists of a fixed-fee payment f that Firm 2 accepts, the respective demands become $p_i = 1 - x_i - x_j$, $i,j = 1, 2; i \neq j$. Thus, Firms 1 and 2 choose the same quantities as when licensing does not hold, i.e., $x_1^f = x_1^n = \frac{1}{2}$ and $x_2^f = x_2^n = \frac{1}{4}$, respectively. However, their respective profits are now $\pi_1^f = \frac{1}{8}$ and $\pi_2^f = \frac{1}{16}$, whereby industry profits amount to $\pi^f = \frac{3}{16}$.

By comparing $\pi^n(t)$ and π^f, the industry profit when licensing does not hold and when licensing occurs through a fixed-fee payment, it follows that $\pi^f < \pi^n(t)$, for all t. That is, licensing the product innovation by means of a fixed-fee contract reduces industry profit and the following result immediately follows.

Lemma 1. *A market-leader firm never licenses its product innovation to a market follower by means of fixed-fee contract.*

Proof. The maximum fixed fee that Firm 1 can charge (when it has all the bargaining power) is $f = \pi_2^f - \pi_2^n$. Hence, its total profit amounts to $\pi_1^f + f = \frac{3-t}{16}$, which satisfies $\pi_1^f + f < \pi_1^n$.

Licensing through a fixed payment is pro-competitive and therefore does not create value for the industry. Consequently, if Firm 1 were restricted to licensing its product innovation for a fixed-fee payment, it would not license it, even though licensing would be socially beneficial.

3.2. Licensing by means of 2PT contract involving per-unit royalty

If licensing is made by means of a two-part tariff (2PT) contract consisting of a fixed fee f combined with a royalty rate r per unit sold and Firm 2 accepts, then the respective demands of the licensor (Firm 1) and licensee (Firm 2) become $p_1 = 1 - x_1 - x_2$ and $p_2 = 1$

[3] Given that the firms have no production costs, ad-valorem or revenue royalties coincide with profit-sharing royalties.

[4] Throughout the paper, the superscript n denotes a no-licensing scenario, and the superscripts f, u and v denote, respectively, licensing by means of a fixed-fee contract, licensing through a two-part tariff contract that involves a per-unit royalty and licensing through a two-part tariff contract that involves an ad-valorem royalty.

$- x_1 - x_2$. Thus, Firm 2 chooses, in the fourth stage of the game, to produce the quantity:

$$x_2^u = \text{argmax}_{x_2}\ \pi_2^u = (1 - r - x_1 - x_2)x_2 \tag{2}$$

Solving Eq. (2) yields $x_2^u = \frac{1-r-x_1}{2}$, which leads Firm 1 to choose, in the third stage, to produce the quantity:

$$x_1^u = \text{argmax}_{x_1}\ \pi_1^u = \left(1 - x_1 - \frac{1 - r - x_1}{2}\right)x_1 + r\frac{1 - r - x_1}{2} \tag{3}$$

yielding $x_1^u = \frac{1}{2}$. Thus, Firm 2 produces $x_2^u = \frac{1-2r}{4}$ and obtains profit $\pi_2^u = \left(\frac{1-2r}{4}\right)^2$. In the second stage of the game, Firm 2 accepts the licence when its profit is no lower than $\pi_2^n = \frac{t}{16}$, the profit it would obtain under no licensing. Finally, in the first stage, Firm 1 chooses the 2PT contract (r,f) that solves:

$$\max_{(r,f)} \pi_1^u = \frac{1 + 2r}{8} + r\frac{1 - 2r}{4} + f,\ \text{s.t}:\ \pi_2^u - f \geq \frac{t}{16},\ r < \frac{1}{2}\ \text{and}\ f \geq 0 \tag{4}$$

Since Firm 2′s participation constraint leads to $f = \left(\frac{1-2r}{4}\right)^2 - \frac{t}{16}$, the problem stated in Eq. (4) can be written as:

$$\max_{r} \pi_1^u = \frac{1 + 2r}{8} + r\frac{1 - 2r}{4} + \left(\frac{1 - 2r}{4}\right)^2 - \frac{t}{16} \tag{5}$$

and solving Eq. (5) yields $r = \frac{1}{2}$. Since this royalty rate leads Firm 2 not to produce, the optimal per-unit royalty is the highest possible rate that allows Firm 2 to be active, i.e., that which holds from $f = 0$. Thus, there is no fixed payment and the contract degenerates in a pure per-unit royalty. This is recorded in the following lemma.

Lemma 2. *A market-leader firm that can use per-unit royalties to license its product innovation sets the per-unit royalty* $r^*(t) = \frac{1-\sqrt{t}}{2}$ *with no fixed-fee payment.*

With this contract, the licensor's payoff amounts to $\pi_1^u = \frac{2-t}{8}$, which equals the profit when licensing does not occur.[5] Although licensing through per-unit royalty makes the industry more collusive (as compared to a no-licensing scenario), Firm 1 produces the same quantity, Firm 2 produces less, and as result, $x^u = \frac{2+\sqrt{t}}{4} < x^n = \frac{3}{4}$; thus $\pi_2^u > \pi_2^n$. However, the licensor cannot extract the licensee's extra profit, because $f = 0$, i.e., there is no fixed payment with which to capture the profit increase $\pi_2^u - \pi_2^n$. Finally, the inability of the licensor to extract the increase in market surplus leads to consumer surplus $CS^u = \frac{(2+\sqrt{t})^2}{32} > \frac{4+5t}{32} = CS^n$, so licensing by means of a pure per-unit royalty would benefit consumers.

3.3. Licensing by means of 2PT contract featuring ad-valorem royalty

Assume now that the license consists of a 2PT contract $(d.f)$, where d, $0 < d < 1$, is an ad-valorem or revenue royalty (which, since there are no production costs, also coincides with a profit-sharing royalty). In this case, Firm 2 chooses to produce, in the fourth stage, the quantity:

$$x_2^v = \text{argmax}_{x_2}\ \pi_2^v = (1 - d)(1 - x_1 - x_2)x_2 \tag{6}$$

and the solution of Eq. (6) is $x_2^v = \frac{1-x_1}{2}$. Thus, Firm 1 chooses, in the third stage, to produce the quantity that solves:

$$x_1^v = \text{argmax}_{x_1}\ \pi_1^v = \left(1 - x_1 - \frac{1 - x_1}{2}\right)x_1 + d\left(1 - x_1 - \frac{1 - x_1}{2}\right)\frac{1 - x_1}{2} \tag{7}$$

which leads to $x_1^v = \frac{1-d}{2-d}$. Thus, $x_2^v = \frac{1}{2(2-d)}$ and consequently, $\pi_2^v = \frac{1-d}{4(2-d)^2}$.

The licensor's payoff consists of the fixed payment $f = \frac{1-d}{4(2-d)^2} - \frac{t}{16}$, the royalty income $\frac{d}{4(2-d)^2}$ and its own market profit $\frac{1-d}{2(2-d)^2}$. Therefore, $\pi_1^v = \frac{1-d}{4(2-d)^2} - \frac{t}{16} + \frac{d}{4(2-d)^2} + \frac{1-d}{2(2-d)^2} = \frac{3-2d}{4(2-d)^2} - \frac{t}{16}$ and the licensor chooses the royalty rate that solves:

$$\max_{d} \pi_1^v = \frac{3 - 2d}{4(2 - d)^2} - \frac{t}{16},\ \text{s.t}:\ \pi_2^v \geq \frac{t}{16} \tag{8}$$

Since the licensor's payoff is increasing in d and the licensee's payoff is decreasing in d, it follows that the optimal contract for the licensor has no fixed fee and degenerates in the ad-valorem royalty that saturates the licensee's participation constraint in Eq. (8), $\frac{1-d}{4(2-d)^2} = \frac{t}{16}$. This yields the result of the following lemma.

[5] If Firm 1 set $r = 0$ and chose a fixed-fee contract, then $x_1^f = \frac{1}{2}$ and $x_2^f = \frac{1}{4}$. Thus, $\pi_2^f = \frac{1}{16}$ and, consequently, $f = \frac{1-t}{16}$. That is, Firm 1's payoff would amount to $\pi_1^f = \frac{1}{8} + \frac{1-t}{16} = \frac{3-t}{16}$, which is lower than π_1^n, the profit it would obtain if licensing would not take place. Thus, under a fixed fee, the market leading firm does not license its innovation.

Lemma 3. *A market leading firm that can use ad-valorem royalties licenses its product innovation by means of the (pure) ad-valorem royalty* $d^*(t) = \frac{2(\sqrt{1-t}-(1-t))}{t}$ *with no fixed payment.*

As occurs in the per-unit royalty regime, the optimal ad-valorem royalty is that which fulfills the licensee's participation constraint, i.e., where the profit if the licence is accepted equals that achieved if the licence is rejected. Thus, the fixed part of the contract is zero. With this ad-valorem royalty, the licensor's payoff amounts to $\pi_1^v = \frac{t}{8(1-\sqrt{1-t})}$.

Finally, from Lemmas 1, 2, and 3, the following result emerges.

Proposition 1. *If the firm that holds the product innovation is the leader firm in the product market, the innovation is licensed (to the market follower) as stated in Lemma 3.*

While licensing through per-unit royalty leaves the licensor with the same market profit as when the innovation is not transferred, and licensing through a fixed-fee payment reduces the licensor's payoff, the ad-valorem royalty increases the profit. This is because ad-valorem royalty allows the licensor to reduce its quantity from $\frac{1}{2}$ to $\frac{2(1-\sqrt{1-t})-t}{2(1-\sqrt{1-t})}$ and, in response, the licensee increase its quantity from $\frac{1}{4}$ to $\frac{t}{4(1-\sqrt{1-t})}$. Overall, total industry output decreases from $x^n = \frac{3}{4}$ to $x^v = 1 - \frac{t}{4(1-\sqrt{1-t})}$, $x^v < x^n$, for all $t \in [0, 1]$, and thus, the product market is more collusive than before licensing.

The licensing contract chosen by a market leader as licensor features an ad-valorem royalty, because it is the contract that makes the industry more collusive. Both per-unit and ad-valorem royalties have an anticompetitive effect, since total production decreases from $x^n = \frac{3}{4}$ to $x^u = \frac{2+\sqrt{t}}{4}$, $x^u < x^n$, when the royalty is per-unit, and to $x^v = 1 - \frac{t}{4(1-\sqrt{1-t})}$, $x^v < x^n$, when the royalty is ad-valorem. Moreover, ad-valorem royalty is a more collusive device since industry production becomes even lower than if per-unit royalty were used, $x^v < x^u$.

4. Game analysis when the patent owner is the market-follower firm

4.1. Licensing by means of 2PT contract involving per-unit royalty

In this case, if Firm 1 (the licensor) chooses the quantity to produce after observing the pre-committed quantity settled by Firm 2 (the licensee) and licensing does not occur, then it follows, from Eq. (1), that the respective quantities are $x_1^n = \frac{4-3t}{4(2-t)}$ and $x_2^n = \frac{1}{2(2-t)}$, where superscript n denotes no licensing. As result, $\pi_1^n = \left(\frac{4-3t}{4(2-t)}\right)^2$ and $\pi_2^n = \frac{t}{8(2-t)}$.

On the other hand, if licensing holds and royalties involved are of per-unit type, Firm 1 (the licensor) chooses, in the fourth stage, to produce:

$$x_1^u = \text{argmax}_{x_1}\ (1 - x_1 - x_2)x_1 + rx_2 \tag{9}$$

that is, $x_1 = \frac{1-x_2}{2}$, and, as result, Firm 2 (the licensee) chooses, in the third stage, to produce:

$$x_2^u = \text{argmax}_{x_2} \left(1 - r - x_2 - \frac{1-x_2}{2}\right)x_2 \tag{10}$$

which leads to $x_2^u = \frac{1-2r}{2}$, and consequently, $x_1^u = \frac{1+2r}{4}$. In the second stage, the licensor offers the contract (r, f) that solves the problem:

$$\max_{(r,f)} \left(f + r\frac{1-2r}{2}\right) + \left(\frac{1+2r}{4}\right)^2, \text{ s.t : } \frac{(1-2r)^2}{8} - f \geq \frac{t}{8(2-t)},\ r < \frac{1}{2}, \tag{11}$$

which can be written as:

$$\max_r \frac{(1-2r)^2}{8} - \frac{t}{8(2-t)} + r\frac{1-2r}{2} + \left(\frac{1+2r}{4}\right)^2 \tag{12}$$

and Eq. (12) yields $r = \frac{1}{2}$. Thus, the optimal royalty that allows Firm 2 to be active in the market is that which solves $\frac{(1-2r)^2}{8} - \frac{t}{8(2-t)} = 0$. In sum, a market-follower firm using per-unit royalties to license its innovation sets the pure per-unit royalty contract $r^*(t) = \frac{1}{2}\left(1 - \frac{\sqrt{t}}{\sqrt{2-t}}\right)$. Since this contract yields the licensor profit $\pi_1^u(t) = \frac{8-7t}{16(2-t)}$, which is strictly lower than π_1^n, its profit when licensing does not hold, a quality-improving innovation owned by a firm that plays as the follower in setting the output in the product market is not licensed to the market-leader competitor when the royalty used is per unit.[6]

[6] The innovation is also not licensed by means of a fixed-fee contract. In this case, $f = \frac{1}{8} - \frac{t}{8(2-t)} = \frac{1-t}{4(2-t)}$. Thus, $\pi_1^f = \frac{1}{16} + \frac{1-t}{4(2-t)} = \frac{6-5t}{16(2-t)}$. By comparing this profit with π_1^n, it follows that $\pi_1^f < \pi_1^n$, for all $t \in (0, 1)$.

4.2. Licensing by means of a 2PT contract involving ad-valorem royalty

If, on the other hand, the market-follower firm licenses its innovation by means of an ad-valorem royalty 2PT contract, it chooses to produce:

$$x_1^v = \text{argmax}_{x_1}\ (1-x_1-x_2)x_1 + d(1-x_1-x_2)x_2 \tag{13}$$

which leads to $x_1^u = \frac{1-(1+d)x_2}{2}$. Licensing featuring an ad-valorem royalty reduces the licensor's quantity, since the effect of a higher market price for royalty revenue is internalized. Thus, the licensee chooses to produce:

$$x_2^v = \text{argmax}_{x_2}(1-d)\left(1-x_2-\frac{1-(1+d)x_2}{2}\right)x_2 \tag{14}$$

which yields $x_2^v = \frac{1}{2(1-d)}$, and consequently, $x_1^v = \frac{1-3d}{4(1-d)}$, which is positive only if $d < \frac{1}{3}$. This leads the licensee to obtain the profit $\pi_2^v = \frac{1}{8}$, whereby the licensor can charge the fixed fee $f = \frac{1}{8} - \frac{t}{8(2-t)} = \frac{1-t}{4(2-t)}$. From here, the licensor's payoff amounts to $\pi_1^v = \frac{1-t}{4(2-t)} + d\frac{1}{8(1-d)} + \frac{1-3d}{16(1-d)} = \frac{1-t}{4(2-t)} + \frac{1}{16}$, regardless of the ad-valorem royalty rate charged. Finally, the fact that $\pi_1^v - \pi_1^n = -\left(\frac{1-t}{2(2-t)}\right)^2$ allows us to state the following result.

Lemma 4. *If the firm that holds the product innovation is the market follower, the innovation remains unlicensed.*

Thus, the innovative firm prefers not to transfer its innovation to the leading firm through any of the contracts considered, so as not to make it more aggressive in the product market than before the licence. In this way, a product innovation in the hands of a firm playing as a market follower is exploited only by that firm, whereby the diffusion of the technology is less than if it were in the hands of the leading firm.

5. Does licensing of a product innovation promote welfare?

In this section, we explore the welfare impact of licensing the innovation when it is in the hands of the market leading firm. When licensing does not occur, consumer surplus amounts to:

$$\begin{aligned} CS^n(t) &= \int_{\theta^*}^1 U_1 d\theta + \int_{\underline{\theta}}^{\theta^*} U_2 d\theta \\ &= \int_{\frac{p_1-p_2}{1-t}}^1 (\theta - p_1)d\theta + \int_{\frac{p_2}{t}}^{\frac{p_1-p_2}{1-t}} (\theta t - p_2)d\theta \\ &= \frac{4+5t}{32} \end{aligned} \tag{15}$$

whereas industry profit is $\pi^n(t) = \frac{4-t}{16}$. Thus, overall welfare is:

$$W^n(t) = \frac{12+3t}{32} \tag{16}$$

On the other hand, when the innovation is transferred (by means of an ad-valorem royalty), it follows that $p_1^v = p_2^v = \frac{t}{4(1-\sqrt{1-t})}$ and that consumer surplus then amounts to:

$$\begin{aligned} CS^v(t) &= \int_{\frac{t}{4\left(1-\sqrt{1-t}\right)}}^1 (\theta - p^v)d\theta \\ &= \frac{32\left(1-\sqrt{1-t}\right) - 8\left(3-\sqrt{1-t}\right)t + t^2}{32\left(1-\sqrt{1-t}\right)^2} \end{aligned} \tag{17}$$

whereas industry profit is $\pi^v(t) = \frac{2+2\sqrt{1-t}+t}{16}$. Thus, aggregate welfare is:

$$W^v(t) = \frac{32\left(1-\sqrt{1-t}\right) - 16t - t^2}{32\left(1-\sqrt{1-t}\right)^2} \tag{18}$$

Finally, by comparing welfare of Eqs. (17) with (15) and welfare of Eqs. (18) with (16), the following result emerges.

Proposition 2. *As compared to a no-licensing scenario, the license of a product innovation owned by a firm that is the leader in the product market is welfare-reducing.*

Licensing a quality-improving innovation to a competitor playing as a follower in setting output in the market increases collusion to the point that the decrease in consumer surplus outweighs the increase in industry profit, and thus, overall welfare is reduced as compared to pre-licensing welfare.

Our analysis in Section 4 indicates that there is room for a policy recommendation on technology transfer, namely, to subsidize the innovation's owner when it is a small firm, which therefore may play as a market follower, in order to encourage it to license its product innovation. This will improve social welfare. In fact, when the market follower has the innovative product and does not license it, the consumer surplus is $CS^n(t) = \frac{16-4t-3t^2}{32(2-t)^2}$ and industry profit is $\pi^n(t) = \frac{16-20t+7t^2}{16(2-t)^2}$. Thus, social welfare is $W^n(t) = \frac{48-44t+11t^2}{32(2-t)^2}$.

On the other hand, if licensing were by means of a fixed-fee payment, then $CS^f = \frac{9}{32}$, $\pi^f = \frac{3}{16}$, and thus $W^f = \frac{15}{32}$. Given that $\frac{15}{32} > \frac{48-44t+11t^2}{32(2-t)^2}$, for all t, then licensing the innovation would increase social welfare. Thus, any subsidy S such that $\frac{(4-3t)^2}{16(2-t)^2} - \frac{1}{16} \leq S < \frac{15}{32} - \frac{48-44t+11t^2}{32(2-t)^2}$ coupled with a prohibition on any per-unit or ad-valorem royalty in licensing contracts would be socially optimal.

Corollary 1. *When the innovative firm is the market follower, a subsidy $S(t)$ such that $\frac{3-5t+2t^2}{4(2-t)^2} \leq S(t) < \frac{3-4t+t^2}{8(2-t)^2}$ would lead that firm to license the innovation, which would be welfare-enhancing.*

6. Conclusions

In this article we have theoretically justified the possibility that the owner of a product innovation (quality-improving innovation) may license it or not based on its position in the product market. In a Stackelberg duopoly model, we found that when the innovation owner is a firm that plays as a market follower in setting the output level in the marketplace, the innovation is not licensed through any of the considered contract types. The innovation owner prefers not to license, to avoid having a more competitive rival that would commit to producing an even higher level of output than due to first-mover advantage. Therefore, from a social perspective there is too little diffusion of such innovations, so there is room for a public policy of subsidizing small (market-follower) firms to diffuse their innovations by means of fixed-fee contracts.

However, when the innovation is in the hands of a firm that plays as the leader at marketplace, licensing holds by means of a pure ad-valorem royalty, and therefore both consumers and society as a whole are harmed. In this case, too much diffusion emerges from a social viewpoint.

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Declarations of Competing Interest

None.

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