Product licensing in a Stackelberg industry

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Abstract

We study in a Stackelberg industry the licensing of a product that embodies an innovation (a quality-improving product). The innovation may be owned by the firm that acts as the leader or follower in the marketplace. If the innovation owner is the market leader, licensing takes place and consists of a revenue royalty with no fixed payment, but is not socially desirable, because it yields a more collusive industry. However, if the innovation owner is the market follower, licensing does not hold, even though it would be welfare enhancing and thus socially desirable. Thus, stimulating licensing by subsidizing a follower firm owning a product innovation would benefit both consumers and society as a whole.

Keywords: Vertical differentiation, licensing, per-unit and ad-valorem royalties, market leader and follower, welfare

JEL Classification: D43, D45

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1. Introduction

Firms that develop and patent innovations not only exploit them for themselves, but also often make them available to direct competitors (Jian and Shi, 2018). For example, Monsanto, which developed and patented the YieldGard Corn Borer and YieldGard Corn Rootworm products that protect from two kinds of corn pests, not only sells both products, but also has licensed them to Pioneer, which has incorporated them into its corn hybrids (Fulton and Yianaka, 2007).

Among the various ways of transferring an innovation,[1] licensing arrangements have gained significant attention in the literature and in practice as a rapid and effective way to improve outcomes for innovative firms. The evidence reveals that more than 50% of product innovation licensing arrangements are applied within industries (Zou and Cheng, 2020) and that a variety of contracts are observed in licensing strategies. For example, in 1998, Eli Lilly licensed the rights of the anticancer drug Ontak to Ligand Pharmaceuticals by charging royalties. In 2004, Accentia Biopharmaceutiacals licensed the chronic sinusitis product BioNasal from Bio Delivery Science International (BDSI) by paying a royalty rate of 14% on net profit. To recover BDSI's investment loss, BDSI then agreed with Accentia to pay a USD2.5 million lump fee and to reduce the royalty rate to 7% (Kulatilaka and Lin, 2006). In the same vein, Arm, the British semiconductor and software design company, trades its intellectual property as follows: "For a fee, anyone can license one of its off-the-shelf designs, tweak it if necessary and sell the resulting chip. Besides licensing revenue, Arm takes a small royalty from every sale of a chip built with its technology".[2]

The literature has suggested several strategic reasons to explain why firms may license their innovations to direct competitors, and also the rationale for the resulting licensing arrangements, namely, to reduce the rivals' incentive to undertake R&D that could convert them into powerful competitors (Gallini, 1984), to dissuade potential competitors from producing similar products, and to reduce competition and reap the technology return, especially in certain phases of the product life cycle (Abernathy and Utterback, 1978; Melumad and Ziv, 2004).

The literature on licensing quality-improving innovations (demand-enhancing innovations) is vast. Li and Song (2009) have studied the interaction between two firms, where one of them has an option to transfer either the latest or the obsolescent technology to its (Cournot) competitor

[1] The literature suggests that firms first focus on product innovation in new markets or product variants, and then, once product opportunities are exhausted, they switch their attention to finding more efficient means of production (Abernathy and Utterback 1978, Klepper 1996, Petsas and Giannikos 2005). Grunert et al. (1997), on the other hand, argues that firms engaged in process innovation may also develop several imitation products or products with a low degree of newness. Mantovani (2005) proposed that product and process innovations are complementary and that firms always prefer simultaneous adoption.
[2] https://www.economist.com/business/2022/06/22/why-everyone-wants-arm

producing a product of lower quality; they show that licensing the new technology is always superior to licensing the obsolescent technology. Zou and Cheng (2020) have studied product innovation (quality-enhancing) licensing, in both exclusive and non-exclusive schemes, each under per-unit combined with fixed fee or revenue royalty combined fixed fee, 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, regardless of whether per-unit or revenue royalty is used, whereas, under exclusive licensing, a two-part tariff (2PT) is optimal. They also show that if fixed-fee licensing is practicable, the licensor favours exclusive licensing, and, furthermore, that licensing improves social welfare in all those schemes.

Neelanjan et al. (2021) discuss licensing between Cournot duopolistic firms in the presence of horizontal and vertical product differentiation. The technology is licensed by the firm that produces the higher quality product to the firm that produces the lower quality product, through a fixed-fee payment if the quality difference (net of cost) and the horizontal differentiation between the two products are relatively low, but through royalty, for any level of quality difference (net of cost) if the horizontal differentiation between the products is relatively low. A similar result holds for 2PT licensing and quota licensing (an output quota plus a fixed fee). It is also shown that the optimal licensing contract is either 2PT or quota licensing. Technology is never licensed from the firm that produces a lower quality product than a rival producing a higher quality product. However, the cross-licensing of technology is sometimes possible, and welfare always increase after licensing.

Chang and Peng (2013) study the optimal licensing contract for a product innovation in a vertically differentiated duopoly. The two firms have different marginal costs and the high-quality firm can license its technology to the low-quality firm. They find that the optimal form of licensing contract depends on the relative marginal costs of the two firms. If the marginal cost of the high-quality firm is relatively high (low), fixed-fee licensing is superior (inferior) to royalty licensing from the viewpoint of the licensor. Surprisingly, consumers are worse off if the quality difference between the two firms is small.

Fang et al. (2015) consider an oligopoly where two downstream firms compete in price and the upstream innovator holds a quality-improving innovation that may create differentiation between the products. They show that non-exclusive licensing performs better than exclusive licensing under both fixed-fee and royalty arrangements, and that the preferred contract consists of a fixed fee only.

The literature that models the market interaction between firms involved in licensing agreements as a simultaneous game does not exhaust, however, all the possibilities regarding competition between those firms. If, in general, large firms produce high-quality goods and small firms produce lower-quality products (Hallak and Sivadasan, 2009), it is plausible that both firms will play different roles in the product market, according to their size – the large firms as market leaders in setting the quantity to be produced, and the small firms as the market followers – and that licensing strategies can differ. Two examples are Procter & Gamble and Ford, which play as leaders in their respective product markets and license their innovations to competitors that play as followers (Jiang and Shi, 2018); at the same time, neither does anything prevent the innovative firm, which becomes the licensor, from being in a follower position in the market. An example of a company that plays as a follower in the semiconductor industry is AMD, 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.

This article extends the analysis of product innovation licensing in a duopoly industry to the case in which the licensor can be either the leading firm in setting output in the product or the following firm. In this setup, we investigate whether or not the patent holder licenses its quality-improving innovation, and if it does, the optimal licensing contract, the impact of that contract on consumers and society as a whole, and, finally, the extent to which decisions depend on the licensor's market position. We also explore the role that a policymaker may play to regulate transactions regarding intellectual property.

We contribute three findings to the licensing literature. First, if the innovation is owned by the leader firm in setting output in the marketplace, licensing takes place through a contract consisting solely of an ad-valorem royalty. The licensor prefers this contract over a fixed-fee contract or a contract that contemplates a per-unit royalty, because it is the device that most increases industry collusion. Second, we offer a rationale for product innovations retained solely by their owners and not licensed to other firms. In particular, if the innovation belongs to the market follower, it is not licensed, because licensing does not create economic value (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). Third, licensing a product innovation to a competitor playing as a market follower is anticompetitive and thus harms consumers more than it increases industry profits. Finally, considering that the literature suggests that a well-targeted subsidy can play a key role in mass adoption of a technology, and so help overcome initial confidence barriers, leverage economies of scale, etc., our model adds an additional rationale for policy interventions in technological diffusion. Specifically, the use of fixed subsidies can promote the diffusion of an innovation in the hands of a (small) firm that plays as a follower in the product market, as, in the absence of the subsidy, this firm would not license the innovation. Thus, subsidization becomes 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.

2. The model

We consider a market in which Firm 1 (the innovative firm) produces a (quality-enhanced) good of quality $q_1 = 1$ and competes with 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. Each consumer i in this market 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 the product 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 the product produced by Firm 1, while consumers in the interval $\left[\underline{\theta}, \theta^*\right]$ will purchase the product produced by Firm 2. Finally, $x_1 = \int_{\theta^*}^{1} d\theta = 1 - \theta^* = 1 - \frac{p_1 - p_2}{1-t}$ and $x_2 = \int_{\underline{\theta}}^{\theta^*} d\theta = \theta^* - \underline{\theta} = \frac{p_1 - p_2}{1-t} - \frac{p_2}{t}$, allowing us to define the firms' residual demands as follows:

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

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 licence may consists 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]

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

The analysis follows a four-stage non-cooperative game. In the first stage, the innovator, 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 contract. In the second stage, the licensee, either the follower or leader, 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 leading firm

3.1. *Licensing by means of a fixed-fee payment*

When the licensor 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 $x_2^f = x_2^n = \frac{1}{4}$. However, their respective profits are now $\pi_1^f = \frac{1}{8}$ and $\pi_2^f = \frac{1}{16}$. Thus, industry profit amounts to $\pi^f = \frac{3}{16}$.

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

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

[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 involving a per-unit royalty and licensing involving an ad-valorem royalty.

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. Consequently, if the licensing agreement consists only of a fixed-fee payment, the firm owning the innovation renounces licensing it, even though licensing would be socially beneficial.

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

If the licensing contract adopts the form of a fixed fee f combined with a royalty rate r per unit sold and Firm 2 accepts, the respective demands become $p_1 = 1 - x_1 - x_2$ and $p_2 = 1 - x_1 - x_2$. Thus, Firm 2 chooses, in the fourth stage of the game, 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, 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 in the contract, only a per-unit royalty.

Lemma 2. *A market-leader firm that can use per-unit royalties to license its product innovation sets the per-unit royalty* $r^*(t) = \frac{1-\sqrt{t}}{2}$ *without a 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 extract the profit increase $\pi_2^u - \pi_2^n$. Finally, the inability of the licensor to extract the increase in market surplus leads to $CS^u = \frac{(2+\sqrt{t})^2}{32} > \frac{4+5t}{32} = CS^n$, 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:

$$x_1^v = \text{argmax}_{x_1}\, \pi_2^v = \left(1 - x_1 - \frac{1-x_1}{2}\right)x_1 + d\left(1 - x_1 - \frac{1-x_1}{2}\right)\frac{1-x_1}{2} \tag{7}$$

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 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:

[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.

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

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 following result.

Lemma 3. *A market leading firm that can use ad-valorem royalties to license its innovation sets the ad-valorem royalty* $d^*(t) = \frac{2(\sqrt{1-t}+t-1)}{t}$ *with no fixed payment.*

As occurs with per-unit royalty, the optimal ad-valorem royalty is that which fulfils 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 $\pi_1^v = \frac{t}{8(1-\sqrt{1-t})}$.

From Lemmas 1, 2, and 3, the following result emerges.

Proposition 1. *A market leading firm with a product innovation licenses it to the market follower as stated in Lemma 3.*

While licensing through per-unit royalty leaves the licensor with the same 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 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 $x_1^n = \frac{4-3t}{4(2-t)}$, $x_2^n = \frac{1}{2(2-t)}$, 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 per-unit, 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 $\pi_1^u(t) = \frac{8-7t}{16(2-t)}$, and this profit is strictly lower than π_1^n, i.e., the profit achieved when licensing does not hold. Hence, a quality-improving innovation owned by a firm that plays as the follower 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 through 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:

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

i.e., $x_1^u = \frac{1-(1+d)q_2}{2}$. 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:

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

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 3. *There is no contract under which a market-follower firm licenses its quality-improving innovation to a market leading competitor.*

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:

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

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

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

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:

$$CS^v(t) = \int_{\frac{t}{4(1-\sqrt{1-t})}}^{1} (\theta - p^v) d\theta = \frac{32(1-\sqrt{1-t}) - 8(3-\sqrt{1-t})t + t^2}{32(1-\sqrt{1-t})^2} \quad (17)$$

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

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

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, licensing of a product innovation by a market leading firm is welfare-reducing.*

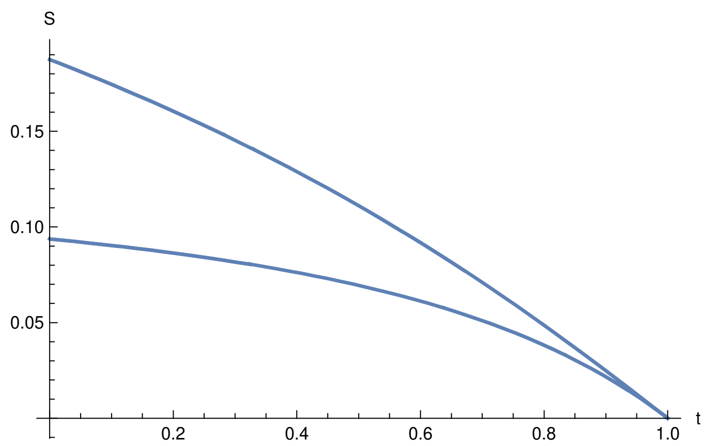
Licensing a quality-improving innovation to a competitor playing as a follower in setting output in the market increases collusion to the point that the decrease in consumer surplus outweighs the increase in industry profit, and thus, overall welfare is reduced as compared to pre-licensing welfare.

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. 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 innovation is in the hands of a market-follower firm, a subsidy* $\frac{3-5t+2t^2}{4(2-t)^2} \leq S(t) < \frac{3-4t+t^2}{8(2-t)^2}$ *would lead that firm to license the innovation, and this would increase social welfare.*

The content of Corollary 1 is illustrated in Figure 1.



6. Conclusions

We investigated in a Stackelberg industry the transfer of a quality-improving innovation belonging to either the leader or follower firm in setting the output level in the product market. We found that when the owner is the market follower, the innovation is not licensed through any of the considered contract types. This firm prefers not to license, to avoid having a more competitive rival that would commit to producing an even higher level of output. Therefore, there is too little diffusion from a social perspective, so there is room for a public policy of subsidizing small (market-follower) firms to diffuse their innovation by means of fixed-fee contracts. However, when the innovation is in the hands of a large (market-leader) firm, 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.

References

Abernathy, W. J. and J. M. Utterback (1978). Patterns of industrial innovation, *Technology Review* 80, 40-47.

Chang, R.-Y. and C.-H. Peng (2013). Cost Asymmetry and Vertical Product Licensing. *Asia-Pacific Journal of Accounting and Economics*

Fang, D., T.J. Richards and B.J. Rickard (2015). Optimal Licensing of Agricultural Patents: Fees versus Royalties, *Journal of Agricultural and Resource Economics* 40, 1-22.

Fulton, M. and A. Yiannaka (2007). Strategic licensing of product innovations. Retrieved from https://ageconsearch.umn.edu/record/9757/files/sp07yi01.pdf

Grunert, K. G., Harmsen, H., Meulenberg, M., Kuiper, E., Ottowitz, T., DeClerck, F., Traill, W.B.and Göransson, G. (1997). A framework for analysing innovation in the food sector, in Product and process innovation in the food industry, ed. B. Traill and K.G. Grunert, Blackie Academic and Professional, London.

Hallak, J. and Sivadasan, J. (2009). Firms' Exporting Behavior under Quality Constraints, NBER Working Paper No. 14928

Jiang, B. and Shi, H. (2018). Inter-competitor licensing and product innovation. *Journal of Marketing Research* 55, 738–751.

Klepper, S. (1996), Entry, exit, growth, and innovation over the product life cycle, *The American Economic Review* 86, 562-583

Kulatilaka, N. and L. Lin (2006). Impact of licensing on investment and financing of technology development, *Management Science* 52, 1824-1837.

Li, C. and J. Song (2009). Technology licensing in a vertically differentiated duopoly, *Japan and the World Economy* 21,183-190.

Mantovani, A.(2005). Complementarity beween product and process innovation in a monopoly setting, http://amsacta.cib.unibo.it/archive/00001753/01/533.pdf

Melumad, N. D., and A. Ziv (2004). Reduced quality and an unlevel playing field could make consumers happier, *Management Science* 50, 1646-1659.

Neelanjan S., S. Kaul and R. Biswas (2021). Technology licensing under product differentiation, *Journal of Economics* 134(3):1-42

Petsas, I., and C. Giannikos (2005). Process versus product innovation in multiproduct firms. *International Journal of Business & Economics* 4(4), 231-248.

Zou, Y. and T.-L. Chen (2020). Quality differentiation and product innovation licensing, *Economic Modelling* 87, 372-382.