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Abstract

We consider a non-producer patentholder with a cost-reducing innovation that can be used in a homogeneous duopolistic industry. To profit from the innovation, the patentholder can decide to sell it, or license it, and if the latter, the number of licences to grant as well as the corresponding contractual terms. We show that the size (value or quality) of innovation is crucial for that decision. The patentholder prefers to sell a small-sized innovation, in which case the buyer further licenses it to the competitor by means of a pure ad-valorem royalty contract. However, if the innovation is moderate or large, the patentholder retains ownership and licenses it to both firms through 2PT contracts involving per-unit royalties. Sale is shown to be welfare superior to licensing for both consumers and firms.

Keywords: Cost-reducing innovation, sale, licensing, per-unit royalty, ad-valorem royalty, welfare

JEL Classification: L13, L24

1. Introduction

Licensing intellectual property rights, such as patents, designs, trademarks, and know-how, is a fundamental means of diffusing innovation by allowing patentholders to be rewarded for their research and development (R&D) efforts. Under licensing, in exchange for some (royalty) payment scheme that ensures a revenue during the contract period, the patentholder grants a licensee the right to use the patented innovation, but retains the right to use it or to license it to another firm (Niu, 2019). Licensing allows technology to be transferred from a patentholder to one or more licensees to the point that the technology transaction is assimilated to innovation diffusion through various licensing contracts. Licensing has emerged as a common strategy for firms in almost all industries, as it simultaneously enables the licensee to acquire a superior technology without engaging in (risky) research and development and the patentholder to generate revenue from the technology while retaining ownership of the patent. The strategic importance of licensing agreements as a means of transferring innovations and generating value from patented innovations is underscored by both average annual growth in the patent licensing market (estimated at 7% from 2020 to 2024)[1] and the fact that the global patent licensing market is expected to be worth $150 billion by the end of 2024.[2]

However, licensing is not the only means to extract value from patented innovations and recuperate R&D expenses. Another major profit avenue is patent sale, i.e., a legal agreement to transfer ownership of the innovation from the patentholder to an interested party (Jeong et al., 2013; Shen et al., 2018; Caviggioli et al., 2020).[3] Thus, the agreed price generates revenue for the patentholder, while the assignee may then sublicense the innovation to a direct competitor (Tauman and Weng, 2012; Banerjee and Poddar, 2019).[4] In this case the innovator loses all rights over the innovation and can no longer use it or license its use to others (Irish, 2005, p. 143).

In practice, licensing and sale are both used by producing and non-producing innovators to commercialize their knowledge assets (Niu, 2020).[5] With the spread of the open innovation paradigm, more companies are selling their technological know-how to other organizations to maximize potential revenue returns (Bianchi et al., 2015). In Taiwan, for instance, so that they

[1] See a report titled "Patent Licensing Statistics: Trends and Insights for 2024" at https://patentpc.com/blog/patent-licensing-statistics-trends-and-insights-for-2024

[2] See a report titled "Patent Licensing vs. Patent Sale: Which One To Opt For Your Business?" by Lumenci Team at https://lumenci.com/blogs/patent-licensing-vs-patent-sale-which-one-to-opt-for-your-business/

[3] In 2010, around 10% of Danish patent-active businesses out-licensed their patents, whereas about 4% of them sold their patents (Niu, 2020).

[4] Other ways a patentholder can transfer its technological knowledge include mergers and acquisitions, partnerships agreements, spin-off creation, and strategic alliances (Caviggioli et al., 2019).

[5] In typical patent broker websites, the most commonly proposed trading modes for a patent are sale and licensing. See, for example, https://sagaciousresearch.com/blog/patent-monetization-choose-between-selling-licensing-and-manufacturing/

can safely enter new markets and avoid any threat of patent litigation, a growing number of firms are actively seeking and acquiring patents (Huang and Chang, 2011), and since 2004, the Taiwanese government-sponsored research organization, Industrial Technology Research Institute (ITRI), has been actively assisting foreign patentholders interested in selling their patents to Taiwanese companies.[6]

Given the potential benefits of licensing an innovation, scholars have overwhelmingly discussed this topic under complete information in two main threads: to whom to grant a licence (Badia et al., 2020), and the optimal licensing contract under various oligopoly models for an outside patentholder (Katz and Shapiro, 1986; Kamien and Tauman, 1986; Kamien, 1992; Sen and Tauman, 2007; Miao, 2013; Doganoglu et al., 2021) and an inside patentholder (Wang, 1998; Kamien and Tauman, 2002; Sen and Tauman, 2007; see also Kamien et al., 1992; Wang et al., 2013; and Sinha, 2016).

However, despite the evidence that selling patent rights is a strategy frequently used in the real world, especially in modern hi-tech industries, the corresponding literature is limited to a handful of empirical works that use data on patent auctions (see, for example, Sneed and Johnson, 2009; Caviggioli and Ughetto, 2013; Fischer and Leidinger, 2014; Odasso et al., 2014; Drivas et al., 2016; Cahoy et al., 2016) and on patent re-sale (see, for example, Serrano, 2010, 2018; Figueroa and Serrano, 2013; Galasso et al., 2013; De Marco et al., 2017; Fusco et al., 2019).[7] However, the strategy of selling patent rights from a patentholder to an incumbent firm is a relatively unexplored area of research that needs to be examined more closely (Tauman and Weng, 2012; Banerjee and Poddar, 2019).

Different monetization strategies for patents entail different risks and returns, with the most appropriate strategy depending on the specific characteristics of the invention (Caviggioli et al., 2020). Licensing implies royalties, while selling, which is a less risky option, implies a fixed-fee payment (Megantz, 2002). However, when uncertainty is low, patentholders tend to prefer to license their patents (Jeong et al., 2013). The decision between licensing and selling, in addition to the specific characteristics of the invention, also depends on the technological field and the corresponding transfer mechanism (Pries and Guild, 2011; Wu et al., 2015).

A crucial decision for a patentholder, therefore, is how to exploit its innovation (Jeong et al., 2012), which may involve a comparison between sale and licensing. Our goal in this paper is to analyse this decision in a very simple model where there is a non-producing patentholder with a cost-reducing innovation that can be transferred to the productive sector through either sale or

[6] Key proposals include paten sale in the right technical area, providing supporting materials to highlight patent value, providing accurate encumbrance information, and using a local broker to overcome the obstacles of understanding and navigating Taiwan's market (Huang and Chang, 2011).
[7] For empirical studies on selling patent rights in technology industries, see Serrano (2010) and Odasso et al. (2014).

licensing. Whereas licensing on an exclusive or non-exclusive basis ensures retention of ownership rights, selling involves transferring full ownership rights to a firm in the industry, which, as an insider licensor, can further choose to sublicense the innovation to a direct competitor.

Regarding whether the patentholder should transfer the innovation by licensing (deciding how and to whom) or by sale, whereby the purchaser may sublicense the innovation to a competitor, we ask, for each alternative, what the consequences are for consumers and for society as a whole, and what policymaking lessons can be drawn regarding favouring or hindering innovation sale.

Our results indicate that the economic value (or quality) of the innovation is crucial for the patent holders' decision. The patentholder prefers to sell the innovation when it leads to a sufficiently small reduction of cost, but license it and maintain the patent rights when the impact of innovation on cost reduction is moderate or large. We also find that if the patentholder sells the innovation, the purchaser sublicenses it to its direct competitor by means of a pure ad-valorem royalty contract, whereas if it is the patentholder who licenses the innovation, then two licences are issued through two-part tariff (2PT) contracts involving a per-unit royalty, whose amount is equal to (less than) the innovation size when the size of innovation is small (large). That the sale of innovation results in a more efficient industry, while with licensing the efficiency of the industry is the same as in the pre-licensing scenario when the innovation is small, leads the patentholder to prefer to sell an innovation that produces a small reduction in costs (low-valued or 'bad' innovation). Contrariwise, when the innovation results in a moderate/large reduction in costs (high-valued or 'good' innovation), the improvement in industry efficiency under licensing (although less than under selling) together with the collusive effect of per-unit royalties lead the patentholder to maintain patent rights and license it.

While technology diffusion is the same under sale as under licensing, the effect on welfare is not however necessarily the same due to differences on contractual terms in each case. In fact, from a welfare perspective, sale is always socially better than licensing because overall industry efficiency is improved. This is because the efficiency of the purchaser of innovation increases with respect to before the transfer because of the fixed-fee payment and the absence of a distorting per-unit royalty, and further improving efficiency is the fact, as an internal licensor holding the patent rights, the purchaser licenses the innovation to the competitor through an ad-valorem royalty contract. However, when the innovation is licensed by the patentholder, this is done by means of two licences, each consisting of a 2PT contract involving a per-unit royalty, r, which may be equal to or less than the innovation size, c: if equal, $r = c$, the industry efficiency does not improve with respect to the pre-licensing scenario, and if less, $r < c$, industry efficiency improves, but less than if the innovation were sold.

Our results suggest that the policymaker should therefore favour selling rather than licensing innovations, or, alternatively, if we interpret innovation sale as (vertical) integration of the patentholder with a downstream firm, the regulator should favour this integration. For small innovations, this translates into a laissez-faire policy because the patentholder's incentive is aligned with social incentives; however, in the case of a large innovation, the regulator should promote, not licensing, but sale of innovations, while providing a subsidy.

The rest of the paper is structured as follows. Section 2 surveys the background literature and Section 3 outlines the model. Sections 4 and 5 describe the behaviour of the patentholder on selling and on licensing the innovation, respectively. Section 6 determines the optimal decision of the patentholder and Section 7 studies the resulting welfare impact. Finally, Section 8 concludes.

2. Related literature

A number of studies have explored the patentholders' problem of choosing between licensing or selling their innovations in different contexts and the welfare impact of each option. For a differentiated duopoly in which one of the firms has a superior technology, Faulí-Oller and Sandonís (2003) compare welfare under a merger and under a licensing contract, showing that whenever both fixed fees and royalties are contractually feasible, licensing is welfare-superior, irrespective of quantity or price competition in the marketplace. If we equate the merger with sale, our welfare outcome is just the opposite; however, our model differs from Faulí-Oller and Sandonís (2003)'s framework in that (i) our patentholder is outside rather than inside the industry, and (ii) we also consider an ad-valorem royalty as contractually feasible. Tauman and Weng (2012) show that, for an external patentholder, it is optimal to sell the patent rights to a single firm in an oligopoly, which has the effect of giving a higher incentive for innovation to an external innovator compared to an incumbent innovator.

Caviggioli and Ughetto (2013) investigate the main drivers of firms' decisions to exploit their patents through licensing or sale, whereas according Miao (2013), even in cases involving minimum asymmetry between downstream firms, fixed-fee licensing of a cost-reducing innovation can generate a higher revenue than auctioning, but not when the issue of multiple licences is optimal.

Jeong et al. (2013), who explore licensing or sale of patents as the main alternatives in technology transfers, find that they are strongly substitutive. Licensing is preferred when uncertainty is low or transaction costs are high, whereas sale is preferred under opposite conditions. Yet, in Jeong et al. (2013), a firm's decision regarding technology transfer relates to patent characteristics, but no consideration is given to strategic interaction between the patentholder and the potential(s) user(s) of innovation, whereas we examine the patentholder's strategic choices regarding licensing versus sale.

Sinha (2016), in considering an outside innovator with a patent that is exploitable in a homogeneous-good Cournot market with ex-ante asymmetric costs of production, shows that value is maximized when the patent is sold in exchange for a fixed-fee payment to an efficient firm who would then (sub)license the innovation to its competitor. This sale of the patent predominates over any licensing mechanism.

In a spatial framework, Banerjee and Poddar (2019) study technology transfer by an outside innovator to asymmetric potential licensees by means of selling or licensing, showing that it prefers sale to a firm who then sublicenses the innovation to a competitor, and moreover, that selling is welfare-superior to licensing. Our findings match the welfare outcome and partially match the patentholder's preference, as, in our context, sale is the preferred strategy only when the innovation is small, whereas licensing is preferred when the innovation is large.

Shen et al. (2018), who investigate the factors that influence the probability of sale/licensing versus internal exploitation of a patent, find an inverted U-shape relationship between patent quality and its probability of being licensed. Patents for low- and high-quality inventions are less likely to be licensed than patents for medium-quality inventions, because of the high transaction cost associated with the former, and the valuable, rare, inimitable, and irreplaceable resources of the company associated with the latter.

Niu (2019) considers an asymmetric duopoly where a relatively inefficient firm has a non-drastic process innovation that it wishes to license or sell. If the initial cost asymmetry is relatively small (significant), the innovator licenses (sells) the innovation to the competitor. Sale is always more profitable if the buyer may license the innovation back to the innovator (reverse licensing) instead of using it exclusively. However, our framework differs from Niu (2019)'s model in that we consider an outside rather than an inside patentholder.

Finally, Caviggioli et al. (2020), in analysing patent transfers by the top 58 US universities from 2002 to 2010, considered patent characteristics associated with monetized patents. They found that 37.0% of the patents granted at the United States Patent and Trademark Office were monetized in some form: 29.7% were licensed, 5.9% were reassigned (sold) to other universities, national laboratories, federal agencies, or non-profit entities, and 1.3% were transferred to companies.

To this literature we add two main results. First, whether an outside patentholder sells or licenses its innovation depends on the size (value or quality) of the innovation. Second, although both sale and licensing of innovation lead to all firms in the industry to adopt the new technology (full adoption), the former is a socially superior mechanism for technology transfer than the latter. This would motivate the regulator to view the sale of technology by an external innovator in a more favourable light than licensing.

3. The model

Consider a duopolistic industry where each firm i, $i = 1, 2$, produces a homogeneous good for a market that exhibits linear demand:

$$p(q) = 1 - q \tag{1}$$

where $q = q_1 + q_2$ is the total amount produced and p denotes the unitary price. Currently, both firm 1 (F1) and firm 2 (F2) produce the good using a standard technology that yields constant returns to scale and leads firms to have marginal or unit cost c, $c > 0$. However, external to the industry there is a patentholder with a superior technology that allows manufacture of the good at a lower (zero) marginal cost. Hence, parameter c measures the size (or quality) of innovation and satisfies the following assumption.

Assumption 1. *The innovation size, c, is such that* $0 < c < 1/2$.

This assumption ensures that the industry will never become monopolized as both firms will coexist in the market by producing positive quantities, i.e., even the firm with the older technology (non-licensee) will produce a positive amount.

Finally, we assume that no firm has a fixed cost of production and both firms are quantity setting players.

The game between the outside patentholder, deciding to either license or sell the innovation, and downstream firms F1 and F2 consists of three stages with the following timing. If, in the first stage, the patentholder chooses to license the innovation, then in the second stage, it decides how many licences to grant and the payments structure of the corresponding contract. If, in the first stage, the patentholder chooses to sell the innovation, then in the second stage, the firm that receives the innovation decides not to sublicense it or to sublicense it, and how, to the competitor.

Finally, in the third stage, the producing firms compete in the marketplace as Cournot players. Irrespective of whether the innovation is licensed by the patentholder or sublicensed by the firm that previously purchased it, we allow for licensing deals by means of a fixed-fee payment alone and/or combined with a royalty, which can be per-unit or ad-valorem (based on each unit produced by the licensee or on a percentage of licensee's sales, respectively). We seek the subgame perfect Nash equilibrium in this game.

4. The patentholder sells the innovation

When the patentholder sells the innovation to one of the producing firms (e.g., F1), this firm becomes the owner of the innovation, and as an internal licensor, can decide whether or not to sublicense the innovation to F2, and as necessary, decides the corresponding contractual terms. Obviously, if the patentholder has all the negotiating power, the sale price will be the maximum value that F1 will obtain from the innovation, i.e., the profit from exclusive exploitation or the profit from shared exploitation through sublicensing, plus additional revenues if F1 sublicenses to its competitor, F2.[8]

4.1. Sublicensing by means of a fixed-fee contract

If F1, once it has purchased the innovation, sublicenses it to its competitor, F2, by means of a non-negative fixed-fee contract f, then F2's profit amounts to $\pi_2^F = \frac{1}{9} - f$, where superscript F denotes the fixed-fee licensing regime. Since, without the new technology, F2's profit would be $\pi_2^N(c) = \frac{(1-2c)^2}{9}$, F1's maximum payment amounts to $f(c) = \frac{1}{9} - \frac{(1-2c)^2}{9} = \frac{4(1-c)c}{9}$. Hence, F1's overall profit is:

$$\pi_1^F + f(c) = \frac{1}{9} + \frac{4(1-c)c}{9} = \frac{1+4c-4c^2}{9} \tag{1}$$

The alternative for F1 is not to license the innovation to its competitor, in which case the profit obtained amounts to $\frac{(1+c)^2}{9}$; this is a better alternative only if $2/5 < c < 1/2$, i.e., only if it is an innovation that reduces the cost of production by a sufficiently large amount.

[8] Of the two alternatives for the patentholder when selling its innovation —not allowing or allowing the purchaser to sublicense it to another firm— the most beneficial is the second alternative.

4.2. Sublicensing by means of a 2PT contract involving a per-unit royalty

If the sublicence consists of a 2PT contract (f, r), where f is a fixed-fee payment and r, $0 \leq r \leq c$, is a per-unit royalty, then F1 and F2 production levels are, respectively, $q_1^U(r) = \frac{1+r}{3}$ and $q_2^U(r) = \frac{1-2r}{3}$, where superscript U denotes the per-unit royalty regime. As a result, F2's profit amounts to $\pi_2^U(r) = \frac{(1-2r)^2}{9}$. Taking into account that the fixed-fee part of the tariff is $f(c,r) \leq \frac{(1-2r)^2}{9} - \frac{(1-2c)^2}{9}$, F1 chooses the per-unit royalty rate that maximizes its total profit, that is:

$$\max_r \left\{\frac{(1+r)^2}{9} + \frac{(1-2r)^2}{9} - \frac{(1-2c)^2}{9} + r\frac{1-2r}{3}\right\} \tag{2}$$

The solution to the problem stated in Eq. (2) is $r = 1/2$, and provided that $c < 1/2$ by Assumption A1, the optimal per-unit royalty is $r^* = c$. Hence, $f^* = 0$. The contract that F1 uses to sublicense the innovation to F2 degenerates into a pure per-unit royalty equal to the innovation size, leaving F2 with the same marginal cost as before; consequently, sublicensing does not improve industry efficiency as compared to non-sublicensing. Finally, F1's total profit, when the contractually feasible royalty is per-unit, amounts to:

$$\pi_1^U(c) + r(c)q_2^U(c) = \frac{(1+c)^2}{9} + c\frac{1-2c}{3} = \frac{1+5c-5c^2}{9} \tag{3}$$

This policy is always better that licensing through a fee, since the per-unit royalty rate $r^* = c$ means that the rival firm is not more competitive than before licensing, and the licensor receives the extra revenues $r\frac{1-2r}{3}$. This policy is also better than not licensing, for all $c < 1/2$, that is, whatever the size of innovation.

4.3. Sublicensing by means of a 2PT contract involving an ad-valorem royalty

In this case the sublicence consists of a fixed-fee payment f combined with an ad-valorem royalty v, $0 \leq v \leq 1$, representing a percentage of F2's sales. After sublicensing, F1's production, $q_1^V(v) = \frac{1-v}{3-v}$ (where superscript V stands for the ad-valorem royalty regime) decreases with v, F1's profit, $\pi_1^V(v) = \frac{1-v}{(3-v)^2}$, decreases with v, and F2's production, $q_2^V(v) = \frac{1}{3-v}$, increases with v. Hence, F1 faces a trade-off when determining the value of v: an increase in v reduces both π_1^V and the fixed-fee part of the contract, but increases royalty earnings, because both F2's production, q_2^V, and the market price increase. Thus, F1 maximizes the sum of its own profit plus the sublicensing revenue, i.e.:

$$\max_v \left\{\frac{1-v}{(3-v)^2} + (1-v)\frac{1}{(3-v)^2} - \frac{(1-2c)^2}{9} + v\frac{1}{(3-v)^2}\right\} \tag{4}$$

which increases with v ($v = 1$ is equivalent to F1's acquisition of F2). Consequently, the optimal ad-valorem licensing degenerates into a pure ad-valorem royalty contract based on the highest ad-valorem royalty acceptable to F2, i.e., that which satisfies:

$$\pi_2^V(v^*) - \pi_2^N = (1 - v)\frac{1}{(3-v)^2} - \frac{(1-2c)^2}{9} = 0 \qquad (5)$$

The solution to Eq. (5) is the ad-valorem royalty rate $v^*(c) = 1 - \frac{5+16c-16c^2-3\sqrt{1+32c-32c^2}}{2(1-2c)^2}$. With this ad-valorem royalty contract, F2's production increases, but both F1's production and industry production decrease, causing the market price to increase. Finally, F1's total profit, when licensing by means of an ad-valorem royalty, amounts to:

$$\pi_1^V(c) + vpq_2^V(c) = \frac{1-v^*}{(3-v^*)^2} + v^*\frac{1}{(3-v^*)^2} = \frac{4(1-2c)^4}{9(3-\sqrt{1+32c-32c^2})^2} \qquad (6)$$

From Eqs. (1), (3), and (6), we obtain the following result regarding the purchaser's behaviour in the second stage of the game.

Lemma 1. *If the patentholder sells the innovation, the purchaser will sublicense it to its competitor through the pure ad-valorem royalty contract* $v^*(c) = 1 - \frac{5+16c-16c^2-3\sqrt{1+32c-32c^2}}{2(1-2c)^2}$.

Thus, the purchaser of the innovation, F1, becomes a potential (internal) licensor, and in sublicensing the innovation to its competitor, F2, prefers to set the highest possible ad-valorem royalty v^*, rather than using per-unit royalty $r^* = c$. This is because although both royalties do not change the effective marginal cost of the licensee, ad-valorem royalty v^* leads to a more collusive industry (it causes F2 to produce more, F1 to produce less, and industry output to be contracted) and F1 can extract the extra profits resulting from the increased collusion. Furthermore, the ad-valorem royalty rate increases with the innovation size, $\frac{\partial v^*}{\partial c} > 0$. Finally, since ad-valorem royalty licensing is better than per-unit royalty licensing, it is a fortiori better than not licensing.

From the previous analysis, we can evaluate the selling price of the innovation. If a firm buys the innovation to the patentholder and then sublicenses it to its competitor as stated in Lemma 1, its profits are as in Eq. (6). The opportunity cost are the profits $\frac{(1-2c)^2}{9}$ that it would obtain if it were its competitor the firm that purchases the innovation.

From Lemma 1, we arrive at the following result.

Lemma 2. *If the patentholder sells the innovation, the selling price amounts to* $S(c) = \frac{4(1-2c)^4}{9\left(3-\sqrt{1+32c-32c^2}\right)^2} - \frac{(1-2c)^2}{9}$.

5. The patentholder licenses the innovation

In this case, the patentholder retains ownership rights to the innovation and decides, as a licensor external to the industry, to whom to license the innovation and what should be the corresponding contractual terms.

5.1. The patentholder grants a single licence

If the patentholder, as an outside licensor, licenses its innovation to a single firm, e.g., F1, by means of a fixed-fee contract, f, then the equilibrium quantities for F1 and F2 after licensing will be, respectively, $q_1^F(c) = \frac{1+c}{3}$ and $q_2^F(c) = \frac{1-2c}{3}$, and the licensing contract will be:

$$f(c) = \frac{(1+c)^2}{9} - \frac{(1-2c)^2}{9} = \frac{(2-c)c}{3} \tag{8}$$

Similarly, if the licence is granted to F1 through a 2PT contract (f, r) composed of a fixed-fee payment, f, combined with a per-unit royalty, r, the equilibrium quantities after licensing will be $q_1^U(c, r) = \frac{1+c-2r}{3}$ and $q_2^U(c, r) = \frac{1-2c+r}{3}$, and the patentholder solves the problem:

$$\max_{(f,r)} \{f + rq_1^U\}, \text{s.t:} f \leq \frac{(1+c-2r)^2}{9} - \frac{(1-2c+r)^2}{9} \tag{9}$$

which yields $r(c) = -\frac{1-c}{2}$. However, if we exclude the possibility that F1's production can be subsidized, then the optimal per-unit royalty amounts to $r^* = 0$. That is, to avoid distorting its production level, the (outside) patentholder does not want to charge a per-unit royalty to F1, and nor does it want to reduce the royalty revenue or the fixed-fee payment. In sum, even if a per-unit royalty is contractually feasible, the patentholder does not include it as part of the contract, and the licensing deal is reduced to the fixed-fee payment given in Eq. (8).

Finally, if the licence is issued through a 2PT contract (f, v), composed of a fixed-fee payment in combination with an ad-valorem royalty, the equilibrium quantities after licensing will be $q_1^V(c) = \frac{1+c}{3}$ and $q_2^V(c) = \frac{1-2c}{3}$, and the patentholder solves the problem:

$$\max_{(f,v)} \{f + v(1 - q_1^V - q_2^V)q_1^V\}, \text{s.t:} f \leq (1 - v)\frac{(1+c)^2}{9} - \frac{(1-2c)^2}{9} \quad (10)$$

This problem becomes $\max_v \frac{(2-c)c}{3}$ once the participation restriction is saturated. Hence, there exists a set of contracts, namely, a fixed-fee alone contract $(f, 0)$, with $f = \frac{(2-c)c}{3}$, a pure ad-valorem royalty contract $(0, v)$, with $v = \frac{3(2-c)c}{(1+c)^2} = 1 - \frac{(1-2c)^2}{(1+c)^2}$, or any 2PT contract (f, v), with $f > 0$ and $0 < v < 1$, all verifying condition $f + v\frac{(2-c)c}{3} = \frac{(2-c)c}{3}$, such that all are equally optimal and render the licensing revenue $\frac{3(2-c)c}{9}$, i.e., the same revenue as under a fixed-fee contract.

This is a standard result when a non-producing innovator grants a single licence under full information (Kamien et al., 1992). Optimal in this case is not to distort the production of the licensee and to extract, through a fixed-fee payment, the increased profit resulting from the superior technology.

5.2. The patentholder grants two licences

If the patentholder licenses the innovation to both firms by means of fixed-fee contracts, the equilibrium profit of each firm i is $\pi_i = \frac{1}{9}$ if both firms are licensed, $\pi_i(c) = \frac{(1+c)^2}{9}$ if firm i is licensed and its competitor j is not licensed, in which case the contract offered to firm i is also a fixed-fee contract as stated in Lemma 1, and $\pi_i(c) = \frac{(1-2c)^2}{9}$ if firm i is not licensed, but competitor j is licensed, in which case the contract offered is also a fixed-fee contract according to Lemma 1. From here, the dominant strategy for each firm i, $i = 1, 2$, is to accept the licensor's offer $f_i(c) = \frac{1}{9} - \frac{(1-2c)^2}{9} = \frac{4(1-c)c}{9}$. Thus, the patentholder obtains the revenue:

$$\pi^F(c) = \frac{8(1-c)c}{9} \quad (11)$$

If, however, the licence to each firm i consists of a 2PT contract (f_i, r_i), $i = 1, 2$, then each firm will produce $q_i^U(r_i) = \frac{1-r_i}{3}$ after licensing. If firm i is not licensed and firm j is licensed —not through a 2PT contract (f_j, r_j), but a fixed-fee contract alone as stated in Lemma 1— then firm i's profit amounts to $\frac{(1-2c)^2}{9}$ and the outside licensor then solves the problem:

$$\max_{(f_i, r_i)} 2\left(f_i + r_i\frac{1-r_i}{3}\right), \text{s.t: } f_i \leq \frac{(1-r_i)^2}{9} - \frac{(1-2c)^2}{9} \quad (12)$$

The solution, $r_i = 1/4$, leads to the 2PT contract:

$$(f_i^*, r_i^*) = \begin{cases} \left(\frac{(2-3c)c}{9}, c\right), & \text{if } 0 \le c \le \frac{1}{4} \\ \left(\frac{1}{16} - \frac{(1-2c)^2}{9}, \frac{1}{4}\right), & \text{if } \frac{1}{4} < c < \frac{1}{2} \end{cases} \tag{13}$$

and, as a result, when the patentholder licences the innovation through contracts involving per-unit royalties, its revenue amounts to:

$$L(c) = \begin{cases} \frac{2(5-6c)c}{9}, & \text{if } 0 \le c \le \frac{1}{4} \\ \frac{1+32c-32c^2}{36}, & \text{if } \frac{1}{4} < c < \frac{1}{2} \end{cases} \tag{14}$$

Finally, if the patentholder grants two licences, each issued through a 2PT contract (f_i, v_i), and provided that each firm's quantity is $q_i^V = \frac{1}{3}$, a similar reasoning as before leads the patentholder to solve the problem:

$$\max_{(f_i, v_i)} \left\{2\left(f_i + v_i\left(1 - q_i^V - q_i^V\right)q_i^V\right)\right\}, \text{ s.t: } f_i \le \frac{1}{9} - \frac{(1-2c)^2}{9} \tag{15}$$

Since firm's performance is independent of v_i, the patentholder can extract the same rents as with a fixed-fee contract alone as $f_i(c) = \frac{4(1-c)c}{9}$. Therefore, the patentholder's revenue is that given in Eq. (11). From here, a comparison of Eqs. (11) and (14) allows us to conclude that, if the patentholder licenses the innovation to F1 and F2, then it offers each the 2PT per-unit royalty contract stated in Eq. (13) to increase market collusion.

From the previous analysis, if we compare the patentholder's payoff on granting a single licence versus two licences, we arrive at the following result.

Lemma 3. *If the patentholder licenses the innovation, it grants two licences by means of the 2PT contracts stated in Eq.* (13) *and the licensing revenue is that given by Eq.* (14).

Hence, Lemmas 1 and 3 state that the same degree of technology diffusion occurs, irrespective of whether the patentholder sells or licenses the innovation, because, if the patentholder sells, the purchaser subsequently sublicenses the innovation to its competitor by means of a pure ad-valorem royalty contract. On the other hand, if the patentholder licenses, then two licences are issued for the innovation via 2PT contracts that include per-unit royalties for an amount equal to (lower than) the cost reduction when the degree of innovation is small (large). Therefore, even though in both cases all firms in the industry receive the innovation, that the structure of payments involved in each commercialization process, sale and license, is different may result in each process having a different impact on welfare.

6. The patentholder's decision

In this section, we solve the first stage of the sale/licensing game, in which the patentholder decides whether to sell or to license the innovation. If the patentholder sells, the price paid by the purchaser is that given in Lemma 2, whereas if the patentholder licenses, its profit is that given in Eq. (13) as indicated in Lemma 3. From here, the following result can be obtained.

Proposition 2. *The patentholder sells the innovation if innovation size, c, is sufficiently small, $0 < c \leq 1/6$, but licenses it if innovation size is moderate or large*, $1/6 < c < 1/2$.

The patentholder's decision as to whether to sell or license the innovation thus depends on whether the size (or quality) of innovation is small or medium/large, yielding, therefore, a small or moderate/large reduction, respectively, in the marginal production costs of the downstream firms. The intuition of this result is as follows. If the patentholder sells the innovation, the buyer (F1) licenses it to its competitor through an ad valorem royalty contract, whereby the industry efficiency improves, and F1's royalty income increases. This results in a higher sales price. However, if the patentholder licenses the innovation two 2PT contracts involving a per-unit royalty r are used, which leads industry efficiency not to improve (improve) when c, the size of innovation, is small (large) since $r = c$ ($r < c$). Therefore, when the innovation produces a small reduction in costs (low-valued or 'bad' innovation), the patentholder prefers to sell it, whereas if the innovation results in a moderate/large reduction in costs (medium- and large-valued or 'good' innovation), then the patentholder prefers to maintain patent rights and license it.

7. Welfare analysis

In this section, we compare the welfare consequences of innovation sale by the patentholder to a single firm in the industry and innovation licensing by the patentholder to all firms in the industry while retaining ownership rights. Accordingly, we examine the impact of the patentholder's strategy on consumer surplus and aggregate welfare, measured as the non-weighted sum of consumer surplus plus industry profits, that is, $W = CS + \pi_1 + \pi_2$. Since there is debate over whether consumer surplus or welfare should be used as a standard for regulatory purposes (Farrell and Katz, 2006),[9] it is important to compare the results for each standard and understand how they differ, assuming that the findings for each criterion are needed for policy recommendations.

If the patentholder sells the innovation to F1 and this firm subsequently sublicenses it to its competitor F2, then, from Lemma 2, it follows that consumer surplus amounts to:

$$CS^S(c) = \frac{1}{18}\left(\frac{7+8c-8c^2-3\sqrt{1+32c-32c^2}}{3-\sqrt{1+32c-32c^2}}\right)^2 \tag{16}$$

According to Eqs. (6) and (7), industry profit is:

$$\pi^S(c) = \frac{4}{9}\left(\frac{(1-2c)^2}{3-\sqrt{1+32c-32c^2}}\right)^2 + \frac{(1-2c)^2}{9} \tag{17}$$

and aggregate welfare amounts to:

$$W^S(c) = \frac{49+80c-80c^2+15\sqrt{1+32c-32c^2}}{48} \tag{18}$$

On the other hand, if the patentholder licenses the innovation to both firms in the industry (as indicated in Proposition 2), then F1 and F2 produce:

$$q_1(c) = q_2(c) = \begin{cases} \frac{1-c}{3}, \text{if } 0 \le c \le \frac{1}{4} \\ \frac{1}{4}, \quad \text{if } \frac{1}{4} < c < \frac{1}{2} \end{cases} \tag{19}$$

As a result, consumer surplus amounts to:

$$CS^L(c) = \begin{cases} \frac{2(1-c)^2}{9}, \text{if } 0 \le c \le \frac{1}{4} \\ \frac{1}{8}, \quad \text{if } \frac{1}{4} < c < \frac{1}{2} \end{cases} \tag{20}$$

and industry profit is:

$$\pi^L(c) = \begin{cases} \frac{2(1-c)^2}{9}, \text{if } 0 \le c \le \frac{1}{4} \\ \frac{1}{16}, \quad \text{if } \frac{1}{4} < c < \frac{1}{2} \end{cases} \tag{21}$$

Hence, from Eqs. (20) and (21), aggregate welfare is:

$$W^L(c) = \begin{cases} \frac{4(1-c)^2}{9}, \text{if } 0 \le c \le \frac{1}{4} \\ \frac{3}{16}, \quad \text{if } \frac{1}{4} < c < \frac{1}{2} \end{cases} \tag{22}$$

[9] EU, US, and Japanese policymakers use consumer welfare (consumer surplus) as the collective criterion, whereas Canada, Australia, and New Zealand policymakers use social welfare as the criterion (Blair and Sokol, 2013; Takashima and Ouchida, 2020).

Finally, adopting a welfare perspective, from Eqs. (16), (17), (20) and (22) the following result can be stated.

Proposition 3. *Both consumers and industry are better off when the innovation is sold rather than licensed.*

Although all potential users end up with the innovation, irrespective of whether the patentholder sells or licenses it, the effect on welfare differs because the contracts for each option do not have the same structure. If the patentholder sells the innovation, full adoption comes from an internal licensor using a pure ad-valorem royalty to transfer the innovation to its competitor in the product market. However, if the patentholder licenses the innovation, full adoption comes from an "outside licensor" by means of two 2PT contracts involving per-unit royalties. Because the ad-valorem royalty contract distorts the firms' behaviour on the quantity produced less than per-unit royalties, a lower price emerges and, hence, the market outcomes are welfare superior to those resulting from the use of per-unit royalties. Thus, both consumers and firms benefit more when the patentholder sells the innovation than when licenses the innovation.

Therefore, if sale of the innovation is understood as vertical integration of the outside patentholder with a firm inside the industry, then the regulator would have an incentive to encourage this (vertical) integration. Moreover, the patentholder's behaviour allows us to suggest that its private incentive is aligned with the social incentive when the degree (or quality) of innovation is sufficiently small, but not when it is moderate or sufficiently large. In this case, a subsidy would be required to persuade the patentholder to sell rather than license the innovation.

8. Conclusion

In this paper, we have analysed the problem of a patentholder with a superior technology that it cannot exploit itself because it lacks production capacity. To benefit from it, the patentholder must therefore decide whether to sell the innovation (transferring its ownership rights) or to license the innovation (retaining its ownership rights) to potential users. When there are two potential users of the innovation that produce a homogeneous good, we find that sale is preferable when the size (economic value or quality) of innovation is sufficiently small, but licensing is preferable when it is moderate or sufficiently large. Therefore, if the innovation causes a small reduction in the cost of production, the patentholder sells it to one of the producing firms, whereas if it produces a significant reduction, then the patentholder prefers to license it and retain the ownership rights of the innovation.

From the perspective of consumers and society as a whole, the results of our model indicate that, regardless of the size of innovation, sale of the innovation is unequivocally better than licensing the innovation, because the market outcome is less collusion in the industry. The regulator would therefore be more inclined to implement measures that result in sale (e.g., through measures that promote integration of the patentholder with a downstream producing firm) than in licensing of innovations.

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Declaration of interest statement

The authors report there are no competing interests to declare.

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