Royalty Licensing
(Preliminary version)

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Abstract

A patent provides its holder the monopolist's right to sell licenses that allow the use of new knowledge during a certain period of time. The empirical evidence reveals that it is most often observed ad valorem royalties than per unit royalties, however the theoretical literature has no prested too much attention to the first ones. In this paper, we provide a justification for the superiority of the ad valorem royalties over the per-unit ones in some circumstances. The possibility of licensing by ad valorem royalty could generate a collusive effect when the patentee is an internal patentee. Including an ad valorem positive royalty in the contract allows the patentee to strategically commit itself to be less aggressive, as its licensing revenues become increasing in the price of the output. Moreover, this collusive effect is high enough in order to induce that consumer surplus is lower with licensing than without it.

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1 Introduction

A patent serves as an incentive for invention by providing the inventor (patentee) a certain period of time during which he controls the diffusion of the invention, so that he can attempt to realize a profit on his investment in research and development.

One source of profit for the inventor is through his own working of the patent. The other, of course, is through licensing of the patent. In the latter case, the specified payment scheme can have various degrees of complexity. In some cases, it simply consists of a fixed license fee. Quite frequently, however, it also includes royalties on a per unit and/or ad valorem basis.

Existing empirical evidence reveals that most of the licensing contracts observed in practice include a positive royalty. Rostoker (1984), for example, finds that royalty alone is used 39% of the time, fixed fee alone 13%, and both instruments together 46%. Calvert (1964), Taylor and Silberston (1973). Ines Macho-Stadler, Xabier Martinez Giralt and David Pérez Castrillo (1996) using a sample of 241 contracts from the data facilitated by the Servicio de Información y Transferencia Tecnológica (Ministerio de Industria, Comercio y Turismo) of Spain conclude that data confirm that most of the contracts have a very simple structure: 83.6% of the contracts are linear (in many cases degenerated, in the sense that they are based either on fixed fee or variable payments only). The remaining contracts present more sophisticated structure: 10.6% of those have two part tariffs. As mentioned in Bousquet et al (1998) the licensing practices of CNET (Centre National d ´Etudes des Telecommunications, the research center of France Telecom) provide a good ilustration of the different payment modes. Within its portfolio in 1990 consisting of 286 contracts, 225 contracts (78 percent) included royalties. Amongst these, only nine contracts specified a per unit royalty while the remaining ones used an ad valorem scheme. The most frequently observed type of contract is based on a combination of fixed fee and ad valorem royalties (179 contracts, representing 63 percent of the total portfolio).

Considerable efforts have been devoted to explain the evidence that says that most of the licensing contracts observed in practice include a positive royalty. These agreements are justified in the literature by appealing, for example, to the possible roles of uncertainty (see Jensen and Thursby (2001) and other references therein), product differentiation (Muto, 1993), the separation of ownership from management (Saracho, 2002), or the degree of competitive behavior in the product market (Saracho, 2005) or by considering the case of a patent holder which is itself a producer within the industry. The literature distinguishes two kinds of patent ownership both of which arise in practice. The first one is that of an independent lab, external patentee, that has no financil interest in the firms of the industry in which the innovation applies. The second one is that of a patentee that is one of the firms in the industry, internal patentee. As it has been shown in the theoretical literature this distinction is key in order to characterize the optimal licensing contract from the point of view of the patentee. Kamien and Tauman (1986) considering an external patentee and a homogeneous good Cournot oligopoly shows that the patentee will prefer the fixed fee mechanism to the per unit royalty.[1] Considering an internal patentee Wang (1998) shows that a per unit royalty is preferred to a fixed fee form from the point of view of the patentee in a homogenous good Cournot duopoly. Wang and Yang (1999) show that the same result arises in a differentiated Bertrand duopoly whenever the goods are close enough substitutes. Finally, Kamien and Tauman (2002) extend Wang's paper to any number of firms and show, among other things, that whenever the number of firms in the industry exceeds a certain threshold number, the patentee is better off licensing by means of a royalty than by auctioning fixed fee licenses.

Despite that the empirical evidence provided above reveals that it is most often observed ad valorem royalties than per unit royalties the theoretical literature has not prested attention to the first ones. Two exceptions are Macho-Stadler et al (1996) and Bousquet et al (1998). In the first case, the compensation paid by the licensee is proportional to the sales revenues collected from the output produced with the innovation. In the second case, the licensee pays a certain amount per unit of output produced with the patented technology. The two papers mentioned above have justified the presence of ad valorem royalties in the licensing agreements in base of asymetric information.

In this paper we compare these two types of royalties, providing a justification for the superiority of the ad valorem royalties over the per-unit royalties in a context of a duopolistic industry that produces a homogeneous non-durable good. This result is due to when the patentee is an internal patentee the ad valorem royalty has a collusive effect. Including an ad valorem positive royalty in the contract allows the patentee to strattegically commit itself to be less aggressive, as its licensing revenues become increasing in the price of the output. Moreover, this collusive effect is high enough in order to induce that consumer surplus is lower with licensing than without

[1] As shown by Muto (1993) that result does not maintain if there is product differentiation.

it. However, when we consider an oligopolistic industry we observe that the patentee prefers the per-unit royalty over the ad valorem royalty.

The rest of the paper is organized as follows. Section 2 presents the model of patent licensing. Section 3 analyzes the two royalty mechanisms considered, and Section 4 concludes with some final remarks.

2 The Model

We consider an oligopolistic industry that produces a homogeneous non-durable goods with $1+n$ firms. In the case of $n=1$, the model is essentially the one presented by Wang (1998), who considers a Cournot duopoly. The cost of entry exceeds the profits an entrant could realize. The firm 1 owns a patent on a non drastic cost-reducing innovation in the sense of Arrow (1962).[2] Consider the inverse demand function for the good produced by the industry is:

$$P = a - bQ \text{ with } Q = q_1 + \sum_{i=2}^{n+1} q_i = q_1 + Q_{-1}$$

where q_i represents the quantity produced by firm $i = 2, ..., n+1$. The marginal cost of production of each firm without the innovation is constant and equal to c. There are no fixed costs of production. The innovation owned by firm 1 reduces the marginal cost of production from c to 0 and the marginal cost of selling licenses is zero[3].

The analysis is modeled as a noncooperative game in three stages. In the first stage, the patentee sets a per-unit royalty or an ad valorem royalty on a take-it-or-leave-it basis. In the second stage, firm i decides whether or not to accept the offer from the firm 1. In the last stage, the firms engage in a non cooperative quantity competition game. Firm 1 sets the royalty rate to maximize its total incomes, that is the sum of the profits from its own production plus the licensing revenues and the rest of firms maximize the profits from their own production minus the cost of the license.

3 Patent Licensing Mechanisms

In this section we proceed to the resolution of the model of patent licensing under both royalty per unit mechanism and ad valorem royalty mechanism, first in a duopolistic industry ($n=1$) (Section 3.1) and then in an oligopolistic general case, that is, when we considered $1+n$ firms (Section 3.2).

[2] A drastic innovation is one where the monopoly price with the new technology is equal to or less than the unit production cost of the old technology. In the context analyzed in this paper the patentee will not license the innovation if it is a drastic one.

[3] Note that as the innovation is a non drastic innovation it must be $a/2 > c$.

3.1 Duopolistic industry

3.1.1 Per-Unit Royalty Mechanism

We look for the subgame perfect Nash equilibrium of the proposed game. Consider that the patentee charges by the license an uniform per-unit of production royalty h. Then the marginal cost of firm 2 with the license is h. It is not difficult to conclude that, in that case, in the third stage of the game the equilibrium production levels of each firm are $q_1 = \frac{a+h}{3b}$ and $q_2 = \max\{\frac{a-2h}{3b}, 0\}$. If h is greater than the reduction in the marginal cost induced by the innovation, c, firm 2 will not buy the license since its marginal cost would then be higher with the innovation than without it.[4] Obviously the licensing payment will depend on the quantity that the licensee produces with the new technology. In the first stage the patentee will then choose the royalty that maximizes his profits.

Therefore, the patentee solves the following problem:

$$\max_h h q_2 (h) + (a - bq_1 - bq_2)\, q_1$$

subject to

$$h \leq c, q_1 = \frac{a+h}{3b} \text{ and } q_2 = \frac{a-2h}{3b}.$$

The resolution of this problem implies that the patentee will set a per unit royalty equal to the reduction of the marginal cost of production induced by the innovation, c. As a result the production of the industry and the patentee profits will be equal respectively, to $Q = \frac{2a-c}{3b}$and $\Pi^{LL} = \frac{a^2+5ac-5c^2}{9b}$.

3.1.2 Ad valorem Royalty Mechanism

Once again we look for the subgame perfect Nash equilibrium so we solve the game by backward induction. At the third stage, each firm will produce that quantity that maximizes its profits given the ad valorem royalty, d, fixed in the first stage.

The licensee and the patentee solves, respectively, the following problems:

$$\max_{q_2} (1-d) \cdot (a - bq_1 - bq_2)\, q_2$$

and

[4] There are situations in which the optimal royalty is greater than the reduction in marginal cost induced by the innovation (see, for example, Fauli-Oller and Sandonis (2002) and Filippini (2005)). This is because the licensor is able to use the licensing agreement as a facilitating device.

$$\max_{q_1} \; (a - bq_1 - bq_2)\, q_1 + d \cdot (a - bq_1 - bq_2)\, q_2$$

The first order conditions of these two problems imply

$$a - bq_1 - 2bq_2 = 0 \text{ and } a - 2bq_1 - (1+d)bq_2 = 0$$

So, in equilibrium, the quantities produced by the firms will be

$$q_1 = \frac{(1-d)a}{b(3-d)} \;, \; q_2 = \frac{a}{b(3-d)} \;.$$

Firm 2 will buy the license if and only if its profits with the innovation are at least as high as those without the innovation, that is $\Pi_0 = \frac{(a-2c)^2}{9b}$. At the first stage the patentee will set the ad valorem royalty that maximizes his total profits subject to the restrictions imposed by the second and third stages of the game. So, it will solve the following problem:

$$\max_{d} \, (a - bq_1 - bq_2)\, q_1 + d \cdot (a - bq_1 - bq_2)\, q_2$$

subject to

$$q_1 = \frac{(1-d)a}{b(3-d)} \;, \; q_2 = \frac{a}{b(3-d)} \text{ and } (1-d) \cdot (a - bq_1 - bq_2)\, q_2 \geq \Pi_0.$$

The solution of this problem implies that the optimal ad valorem royalty, the production of the industry and the patentee profits are respectively,

$$\begin{aligned}
d^* &= \frac{3(8c^2 - 8ac - a^2 + a(a^2 + 32ac - 32c^2)^{1/2})}{2(a^2 - 4ac + 4c^2)}, \\
Q^{LA} &= \frac{-7a^2 - 8ac + 8c^2 + 3(a^2(a^2 + 32ac - 32c^2))^{1/2}}{3b(-3a + (a^2 + 32ac - 32c^2)^{1/2})}, \text{ and} \\
\Pi^{LA} &= \frac{4(a-2c)^4}{9b(-3a + (a^2 + 32ac - 32c^2)^{1/2})^2}.
\end{aligned}$$

3.1.3 Comparison of the two Royalty Licensing Mechanisms

Comparing the patentee profits under per unit royalty and under ad valorem royalty we may establish the following proposition regarding the royalty licensing mechanism preferred by the patentee:

Proposition 1

From the point of view of an internal patentee of a non-drastic innovation licensing by means of an ad valorem royalty is superior to licensing by means of a per unit royalty.

Proof

Comparing the patentee profits under the ad valorem royalty, Π^{LA}, and those under the per unit royalty, Π^{LL}, we get that

$$\Pi^{LA} - \Pi^{LL} = \frac{2[-a^4 - 19a^3c + 3a^2c^2 + 32ac^3 - 16c^4 + a(a^2+5ac-5c^2)(a^2+32ac-32c^2)^{1/2}]}{3b(-3a+(a^2+32ac-32c^2)^{1/2})^2}.$$

So the sign of $\Pi^{LA} - \Pi^{LL}$ is equal to the sign of $-a^4 - 19a^3c + 3a^2c^2 + 32ac^3 - 16c^4 + a(a^2 + 5ac - 5c^2)(a^2 + 32ac - 32c^2)^{1/2}$. As $(-a^4 - 19a^3c + 3a^2c^2 + 32ac^3 - 16c^4)^2 + a^2(a^2 + 5ac - 5c^2)^2(a^2 + 32ac - 32c^2) = 4c(a - 2c)^6(a - c)$ and $2c < a$ the Proposition 1 follows. ■

Licensing by means of an ad valorem royalty is superior to licensing by means of a per-unit royalty when the innovation is non-drastic. From the first order condition of the maximization problem solved by the patentee at the third stage is obvious that the patentee behaves more agressively than in the case in which the ad valorem royalty is zero. The reason is that the patentee has an additional incentive to behave less aggressively in the market: by setting a lower quantity, it increases the price and, subsequently, the sales of the licensee and so the revenues from licensing.[5] In turn this implies that although the per unit royalty allows to the patentee to increase the marginal cost of production of its rival by the amount of the royalty it prefers the ad valorem royalty.

Next we are going to evaluate the effects of ad valorem royalty from the point of view of consumers and social welfare, measured as the sum of firms‘ profits and consumer surplus, compared with those corresponding to the per unit royalty and to no licensing.

Proposition 2

i) Social welfare and consumer surplus are higher with the per unit royalty than with the ad valorem royalty.

[5] In an interesting paper Fauli and Sandonis (2002) mention that this effect would appear in a context as the one we consider. However, they do not analyze neither the ad valorem royalties nor the superiority of this mechanism over the per unit royalty.

ii) Social welfare is greater and consumer surplus is lower with licensing by means of an ad valoren royalty than without licensing.

Proof

As with the innovation the marginal production cost is equal to zero social welfare, as consumer surplus does, increases with the quantity produced. As the optimal per unit royalty is equal to the reduction in the marginal cost of production induced by the innovation it is clear that under per-unit royalty the production level is identical to the one corresponding to no licensing. Moreover comparing the production of the industry under ad valorem royalty and per unit royalty we get that

$Q^{LA} - Q^{LL} = \frac{a^2+11ac-8c^2-(a+c)(a^2+32ac-32c^2)^{1/2}}{3b(3a-(a^2+32ac-32c^2)^{1/2})}$. Given that $(a^2 + 11ac - 8c^2)^2 - (a + c)^2(a^2 + 32ac - 32c^2) = -12c(a - 2c)^3 < 0 \ \forall c < a/2$, the minimum value of the function $F(m) = 3a - (a^2 + 32am - 32m^2)^{1/2}$ is 0 which is reached in $m = a/2$ we may conclude that social welfare, and consumer surplus, are higher with the per unit royalty than with the ad valorem.

From the result above we may also conclude that consumer surplus is higher without licensing that with ad valorem licensing. By comparing social welfare in these two last cases, W^{LA} and W^{NL}respectively we get

$W^{LA} - W^{NL} = \frac{a(a^4+24a^3c+3a^2c^2-80ac^3+48c^4)-(a^2+8ac-11c^2)(a^4+32a^3c-32a^2c^2)^{1/2})}{3b(-3a+(a^2+32ac-32c^2)^{1/2})^2} > 0 \ \forall c \in (0, 1/2)$ given that $(a^4+24a^3c+3a^2c^2-80ac^3+48c^4)^2-(a^2+8ac-11c^2)^2(a^4+32a^3c-32a^2c^2) = 12(5a - 6c)(a - 2c)^5c^2 > 0 \ \forall c \in (0, 1/2)$ and Proposition 2 follows. ■

The Proposition above implies that due to the collusive effect induced by the the ad valorem royalty licensing will hurt consumers.

3.2 Oligopolistic industry

3.2.1 Per-unit royalty mechanism

Generalizing the result of section 3.1.1 for n firms, it is easy to obtain the production levels at the third step of the game:

$q_1 = \frac{a+nh}{b(2+n)}$ and $q_i = \max\{\frac{a-2h}{b(2+n)}, 0\}$.

Therefore, the patentee solves the following problem:

$$\max_h \ hnq_i\,(h) + (a - bq_1 - nbq_i)\,q_1$$

subject to

$$h \leq c, q_1 = \frac{a+nh}{b(2+n)} \text{ and } q_i = \frac{a-2h}{b(2+n)}$$

Finally the production of the industry and the patentee profits will be equal respectively, to $Q = \frac{a(1+n)-nc}{b(2+n)}$ and $\Pi^{LL} = \frac{a^2+(4+n)nc(a-c)}{b(2+n)^2}$.

3.2.2 Ad valorem royalty mechanism

Let us assume that it is optimal from the patentee point of view to sell licenses to all firms in the industry.

At the third stage, each firm will produce that quantity that maximizes its profits given the ad valorem royalty d fixed in the first stage.

The licensees and the patentee solves, respectively, the following problems:

$$\max_{q_i}(1-d)\left(a-bq_1-bQ_{-1}\right)q_i \qquad i=2,...,n+1$$

and

$$\max_{q_1} \ \left(a-bq_1-bQ_{-1}\right)q_1+d\left(a-bq_1-bQ_{-1}\right)Q_{-1}$$

The first order conditions of these two problems imply

$$a-bQ_{-i}-2bq_i=0 \text{ and } a-2bq_1-(1+d)bQ_{-1}=0$$

So, in equilibrium, assuming interior solutions, the quantities produced by the firms will be

$$q_1=\frac{[1-nd]a}{b[2+n(1-d)]}\ ,\ q_i=\frac{a}{b[2+n(1-d)]}\ .$$

Firm i will buy the license if and only if its profits with the innovation, $\frac{(1-d)a^2}{b[2+n(1-d)]^2}$, are at least as high as those without the innovation, given the behavior of the other firms, that is $\Pi_i = \frac{[a-c(n+1)+cd(n-1))]^2}{b[2+n(1-d)]^2}$.[6]

[6] These profits are obtained by solving the following problems:

$$\max_{q_i}(1-d)\cdot\left(a-bQ\right)q_i \qquad i=3,...,n+1$$

$$\max_{q_1} \ \left(a-bQ\right)q_1+d\cdot\left(a-bQ\right)\left(Q_{-1}-q_2\right)$$

and

At the first stage the patentee will set the ad valorem royalty that maximizes his total profits subject to the restrictions imposed by the second and third stages of the game. It is not difficult to conclude that the ad valorem royalty set by the patentee will be the solution of the following equation

$$\frac{a^2(1-d)}{b[2+n(1-d)]^2} - \frac{[a-c(n+1)+cd(n-1))]^2}{b[2+n(1-d)]^2} = 0$$

and the patentee profits will be $\frac{a^2}{b(2+n(1-d))^2}$.

We can only obtain a manageable expression for d if $n = 1$. So, we are going to provide a numerical example in order to show that the patenteee may prefer the per-unit royalty to the ad valorem royalty when $n > 2$. Let us consider that $n = 2$, $a = 20c$. In this case the optimal ad valorem royalty is $d = 0.402$ and the patentee profits will be $\frac{a^2}{10.214b}$ lower than those corresponding to the per unit royalty, $\frac{a^2}{10.191b}$. Moreover, social welfare, $0.451\frac{a^2}{b}$ will be lower than without licensing, $0.469\frac{a^2}{b}$.

4 Concluding Remarks

A patent provides its holder the monopolist's right to sell licenses that allow the use of new knowledge during a certain period of time. The empirical evidence reveals that it is most often observed ad valorem royalties than per unit royalties, however the theoretical literature has no prested too much attention to the first ones. In this paper, we provide a justification for the superiority of the ad valorem royalties over the per-unit ones in some circumstances. The possibility of licensing by ad valorem royalty could generate a collusive effect when the patentee is an internal patentee. Including an ad valorem positive royalty in the contract allows the patentee to strategically commit itself to be less aggressive, as its licensing revenues become increasing in the price of the output. Moreover, this collusive effect is high enough in order to induce that consumer surplus is lower with licensing than without it.

Lastly it is easy to show that in the case of an external patentee his profits will be greater with ad valorem royalty than with per-unit royalty. However, the patentee will prefer to sell the licenses by means of a fixed fee or an auction. The reason is that the profits that the patentee may guarantee under the ad valorem royalty are

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$$\max_{q_2} \ (a - bQ - c)\, q_2$$

identical to the profits that he would obtain selling the licenses to all the firms in the industry by means of the fixed fee mechanism (proofs are at disposal under request).

REFERENCES

Arrow, K. J.: “Economic Welfare and the Allocation of Resources for Inventions,” in R.R. Nelson ed., *The Rate and Direction of Inventive Activity,* Princeton University Press (1962).

Bousquet, A., Cremer, H., Ivaldi, M., Wolkovicz, M.: “Risk sharing in licensing”, *International Journal of Industrial Organization* 16, 535-554 (1998).

Fauli-Oller, R., Sandonis, J.: “Welfare Reducing Licensing,” *Games and Economic Behavior* 41, 192-205 (2002).

Filippini, L.: “Licensing Contract in a Stackelberg Model,” *The Manchester School* 73, 582-598 (2005).

Jensen, R., Thursby, M.: “Proofs and Prototypes for Sale: The Licensing of University Inventions,” *American Economic Review* 91, 240-259 (2001).

Kamien, M. I., Tauman, Y.: “Fees versus Royalties and the Private Value of a Patent,” *Quarterly Journal of Economics* 101, 471-491 (1986).

Kamien, M. I., Tauman, Y.: “Patent Licensing: The Inside Story,” *The Manchester School* 70, 7-15 (2002).

Macho-Stadler, I., Martínez-Giralt, X., Pérez-Castrillo, J. D.: “The role of information in licensing contract design,” *Research Policy* 25, 25-41 (1996).

Muto, S.: “On Licensing Policies in Bertrand Competition,” *Games and Economic Behavior* 5, 257-267 (1993).

Rostoker, M.: “A Survey of Corporate Licensing,” *IDEA-The Journal of Law and Technology,* PTC Research Report 24, 59-92 (1984).

Saracho, A. I.: "Patent Licensing under Strategic Delegation," *Journal of Economics & Management Strategy* 11, 225-251 (2002).

Saracho, A. I.: "The Relationship between Patent Licensing and Competitive Behavior," *The Manchester School* 73, 563-581 (2005).

Taylor, C., Silverston Z.: *The Economic Impact of the Patent System.* Cambridge: Cambridge University Press (1973).

Wang, X. H.,: "Fee versus Royalty Licensing in a Cournot Duopoly Model," *Economics Letters* 60, 55-62 (1998).

Wang, X. H., Yang, B. Z.: "On licensing under Bertrand competition," *Australian Economic Papers* 38, 106-119 (1999).