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ABSTRACT

A patent holder owning a two-period lasting innovation is unable to push it into the market, so it is licensed to a downstream user with production capabilities to market it. The production cost of this firm can be low or high, but the patent holder has only a prior on this fact. To discover the patent value, it may design a separating or a signaling short-run licensing contract. In the first case, the contract of period 1 includes a fixed fee for the efficient user and a two-part contract for the inefficient user; in the second, it consists of a fixed fee alone for both types of user. From the patent holder's viewpoint, a screening contract is better than a signaling contract only when the user is likely to become inefficient in marketing the innovation and the cost difference is not very high. Otherwise, a signaling contract is preferred. Hence, the coexistence of the different licensing schemes observed in practice can be rationalized by the use of different devices (screening or signaling) aimed at alleviating the effects of opportunistic behavior. From a social perspective, although screening is generally superior to signaling to extract hidden information—signaling is preferred to screening under certain conditions.

Keywords: Licensing, asymmetric information, screening, signaling

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1. Introduction

Patent licensing is one of the most relevant methods of technology transfer between firms and also a significant revenue source for both independent and inside patent holders (Anand and Khanna, 2000; Arora and Fosfuri, 2002). Theoretical and empirical work on the optimal form of licensing contracts is vast. Findings show that, in a complete information context, fee contracts are better (worse) than royalty contracts when the patent holder is outside (inside) the industry (Kamien and Tauman, 1986; Katz and Shapiro, 1985, 1986; Kamien et al., 1992; Sen, 2005; Sen and Tauman, 2007). Contrariwise, double-sided moral hazard problems and optimal risk allocation justify the existence of two-part (fee plus royalty) contracts (Poddar and Sinha, 2002; Beggs, 1992; Gallini and Wright, 1990; Choi, 2001; Viswasrao, 2007; Cebrián, 2009).

This paper tackles a relevant issue to understand optimal structure of licensing contracts in the presence of asymmetric information. Unlike standard literature on licensing under asymmetric information, where a fixed set up is established to disclose private information (screening or signaling models), this paper compares the outcome of both of them for the patent holder and the society as a whole. In particular, this research sheds light on how the choice among different licensing schemes is carried out to mitigate opportunistic behavior. In other words, it shows the impact which adverse selection may have on the form of payment in licensing arrangements when the patent holder licenses the innovation to a firm with production capacity to market it.

In the model, the (upstream) patent holder owns a patented innovation for two time periods but has no production capabilities to market it by itself, thus being forced to sell it to a (downstream) firm. Furthermore, the patent holder is unaware of the efficiency level of the innovation user (the value of the innovation), but only knows for sure that production cost may adopt a certain value (low or high) according to a given probability. To infer true cost, the patent holder may offer the licensee a separating contract (i.e., screening) or allow the licensee signaling its type (i.e., signaling). To this end, the licensing process between an upstream patent holder and a downstream licensee is examined within a two-period model. In the model, only short-term (fixed-fee and royalty) contracts are allowed. That is, the patent holder neither solves a unique inter-temporal optimization problem nor determines the whole vector of payments for the expected patent-lifetime by considering the inter-temporal participation and incentive constraints of the firm. Such a contractual structure may be based on the assumption of limited liability constraints, which lead the innovation user to obtain non-negative profits in any period and any realization of production costs when marketing the innovation.[1]

In the licensing-screening game, the patent holder offers in period 1 a menu of contracts and the licensee chooses a particular contract from the offered menu. Information becomes complete in period 2. On the other hand, in the licensing-signaling game, the patent holder offers the same contract to both types of licensee in period 1 and it is the licensee who discloses its private information through the publicly-observable output level of period 1. Thus, period 2 also becomes a complete information period as in the licensing-screening game.

[1] A well-known result in repeated agency models is that a long-term contract always dominates (at least weakly) a short-term contract. Thus, without considering limited liability constraints, a optimization problem in which the principal considers the inter-temporal participation constraint of the firm would dominate (from the principal's perspective).

In this context, the main goal of this paper is comparing the equilibrium outcome of the screening and signaling games to analyze the optimal method—both for the patent holder and the society as a whole—in order to extract hidden information. In other words, what optimal licensing-contract structure allows the patent holder and the society restoring complete information at the lowest cost? This novel approach sharply differs from others previously used in specialized literature, since it compares different information-revelation schemes instead of adopting a given framework of information revelation (identification/screening or signaling).

Three main conclusions can be drawn from analysis: Firstly, if the patent holder offers a separating contract, the optimum contract in period 1 includes a fixed fee aimed at the efficient firm and a fixed-fee-plus-royalty combination aimed at the inefficient firm. The former firm does not distort its production level, while the latter firm distorts its production level downward due to the higher marginal cost imposed by the royalty. However, if the patent holder allows the firm signaling its type, there is then a separating equilibrium in which the optimum contract in period 1 consists on a fixed-fee for both firm types. The inefficient firm does not distort its production level, while the inefficient firm distorts its production level downward to signal its inefficiency and thus pay a lower fee in period 2. This finding then confirms that, under adverse selection, optimal licensing contracts do not adopt one only form but may include a different payment structure depending on model parametric configuration. Particularly, fee-plus-royalty (in the screening variant of the licensing game) or fee-only (in its signaling variant) payments may be adopted as licensing arrangement.

Secondly, from the patent holder's viewpoint, a menu of contracts in period 1 is better than a signaling contract, but only when the firm is likely to become inefficient to market the innovation and the difference in production costs is low enough. In this case, a screening contract leads the inefficient firm to lower production distortion than with a signaling contract. Thus, the expected income of the patent holder increases. Under any other circumstances, the patent holder prefers a signaling contract to a menu of contracts, since signaling involves little cost. This is relevant to understand how asymmetric information accounts for the different payment types observed in licensing contracts. Both screening and signaling lead the inefficient firm to downward production-level distortion in period 1; however, the source of this distortion differs from one case to another. Under a screening contract, distortion is exogenous due to the increased cost of the inefficient firm, attributable to the royalty imposed by the patent holder. However, under a signaling contract, distortion at the production level of the inefficient user is endogenous, since this firm signaled itself as such in period 1 so as to pay a lower fee later on.

Thirdly, from a social perspective, within most of the space defined by the probability of becoming an efficient user and production cost difference, screening the efficiency level of the licensee creates greater expected total welfare than a signaling contract. Under either screening or signaling, the amount produced in period 1 by the efficient user is not distorted as compared to the profit-maximizing quantity. However, the output of the inefficient licensee is distorted downward as compared to the profit-maximizing amount. Although distortion under a signaling contract may be lower than under a screening contract, the former leads to welfare loss, due to decreased firm's profit (or patent holder's income) and consumer surplus in period 1. Distortion due to a screening contract, however, causes (a welfare loss but, especially) welfare re-distribution: it reduces the patent holder's income and the consumer surplus in period 1, but allows the efficient licensee to obtain informational rents in such period. Thus, when not only the patent holder is considered but also innovation consumers and users, a screening contract is generally superior (except when high enough values of the probability of being an efficient innovation user are coupled to a large enough difference in production costs). In this case, signaling cost is so little relative to screening cost that the former is advantageous to the patent holder and the society as a whole. This means that—both in this small region and in the region where screening is optimal for the patent holder—private and social incentives are aligned.

To sum up, this paper comprises both a positive aspect, explaining the different contractual arrangements observed in real licensing contracts (fee-only payments as well as fee-plus-royalty combinations), and a normative aspect, examining the welfare implications of different licensing schemes.

The rest of this paper is structured into four sections: Section 2 includes model description, Section 3 develops a licensing-screening and a licensing-signaling equilibriums, and Section 4 compares both equilibriums from the perspective of the patent holder and the society as a whole, while conclusions are drawn in Section 5. Proofs are reported in the Appendix.

2. The model

Consider an upstream patent holder lacking of production capacity which owns an expectedly marketable innovation patented for two production periods

(t=1,2). This innovation is launched by a downstream firm which produces a new good. Demand for this good is given by

$$p_t(q_t) = 1 - q_t \ , \tag{1}$$

in each period t, where p_t stands for the unit price in t when production level is q_t. Both the patent holder and the licensee have complete information on the demand given in (1).

The licensee faces a linear cost function $c_t(q_t) = \tilde{c} q_t$ in each period, where $\tilde{c}$ is the marginal (and average) production cost in innovation marketing. The firm's cost is given and privately known by the firm, and the patent holder does not know such cost. However, it is common knowledge that the cost of the licensee is independent, drawn from a probability distribution that assigns probability μ, $0<\mu<1$ to low-cost production (zero cost, for simplicity) and probability 1-μ to high-cost level c, $c>0$. For the sake of regularity, the following property is assumed:

Assumption 1. Parameters μ and c are so that $\mu + c < 1$

This assumption ensures that, if the licensee becomes inefficient to market the innovation, it will always produce a positive amount of output in the first period (of the licensing-screening game). Hence, it defines the (μ,c)-region of parameters where the equilibrium of such a game involves that the licensee is active in the industry, regardless of its cost type.

Finally, there is no discount factor between periods and both the patent holder and the licensee are risk-neutral players. Contracts in each production period are assumed to be either fixed-fee or royalty contracts. Throughout this paper, we look for the separating equilibrium in both screening and signaling games.

3. Equilibrium analysis

3.1 First best

If the patent holder owns the same information as the innovation user, the licensing contract defining the first best is that obtained by solving the patent holder's problem:

$$\max_{(F_{kt},r_{kt})} \Pi_t^{\mathrm{PH}} = F_{kt} + r_{kt} \cdot q_{kt}(r_{kt}) \qquad (2)$$

for each type *k*, *k*=*L*,*H*, of licensee in each period *t*, *t*=1,2.[2] Given that royalty rates distort the licensee's production through increased marginal cost—they lead to a lower overall surplus to be shared by the licensee and the patent holder (Kamien and Tauman, 1984, 1986; Kamien et al., 1992; Poddar and Sinha, 2002). Therefore, the optimal licensing strategy in each period is to charge only a fixed fee, so the licensee receives its reservation payoff (zero). Hence, $F_{kt} = (1-\tilde{c})^2/4$ is the short-term contract and the patentee obtains the whole profits of each type. This result can be recorded in the following lemma, where subscripts *L* and *H* denote low- and high-cost firm, respectively.

Lemma 1. *The first-best licensing contract is a fee contract:* $F_{Lt} = 1/4$ *if the firm is efficient and* $F_{Ht} = (1-c)^2/4$ *if inefficient; there is no royalty rate,* $r_{Lt} = r_{Lt} = 0$.

3.2 The licensing-screening game

[2] *L* denotes the low-cost user of the innovation and *H* stands for the high-cost licensee.

In the licensing-screening game, in period 1 the patent holder screens each type of licensee by offering a menu of contracts (screening contract), each charging a fee and a per-unit royalty. The licensee then chooses a particular contract from the menu and the patent holder infers the cost of the licensee. Thus, in period 2, types are observable because the principal observes the contract accepted in the previous period. Consequently, information becomes complete in period 2.[3]

I only consider short-term licensing contracts. That is, the principal (the patent holder) neither solves a unique inter-temporal optimization problem nor determines the whole payment vector for the entire patent lifetime (two periods) by considering the inter-temporal participation and incentive constraints of the firm. This contractual structure is based on the assumption of the limited liability constraints which lead the agent (the innovation user) to have non-negative profits in any period and production-cost realization. Without this assumption, an optimization program in which the principal would consider the inter-temporal participation constraint of the agent would obviously be dominant from the principal's viewpoint.

Let $\{(F_{L1}, r_{L1}), (F_{H1}, r_{H1})\}$ denote the menu of contracts offered to the licensee in period 1, thus under asymmetric information. The first contract from the menu, (F_{L1}, r_{L1}), is aimed at the low-cost firm and the second, (F_{H1}, r_{H1}), at the high-cost firm. Such a menu must solve the patent holder's problem

$$\max_{(r_{L1}, r_{H1})} \Pi_1^{\mathrm{PH}} = \mu[F_{L1} + r_{L1} \cdot q_{L1}(r_{L1})] + (1-\mu)[F_{H1} + r_{H1} \cdot q_{H1}(r_{H1})] \quad (3)$$

subject to

[3] In this (complete information) period, fee-only contracts are the optimal licensing scheme for the patent holder.

$$-F_{L1}+\frac{(1-r_{L1})^2}{4}\geq 0\ , \qquad (4)$$

$$-F_{H1}+\frac{(1-c-r_{H1})^2}{4}\geq 0\ , \qquad (5)$$

$$-F_{L1}+\frac{(1-r_{L1})^2}{4}\geq -F_{H1}+\frac{(1-r_{H1})^2}{4}-\frac{(1-c)^2}{4}+\frac{1}{4}\ , \qquad (6)$$

and

$$-F_{H1}+\frac{(1-c-r_{H1})^2}{4}\geq -F_{L1}+\frac{(1-c-r_{L1})^2}{4}-\frac{1}{4}+\frac{(1-c)^2}{4}\ . \qquad (7)$$

Therefore, the licensee chooses a particular contract from the menu. Conditions (4) and (5) are the participation constraints for the efficient and inefficient firm, respectively. On the other hand, (6) and (7) represent the incentive compatibility conditions for the efficient and inefficient user, respectively.

Obviously, contract (F_{L1},r_{L1}), aimed at the efficient firm, must enable this firm to get (informational) rents in equilibrium. Since royalties distort production and surplus, a reduction in the amount of r_{L1} to zero and an increase in the corresponding fixed fee F_{L1} subjected to the fulfillment of condition (6) would increase the rents accrued by the patent holder. Furthermore, this adjustment does not violate condition (7). This enables that

$$F_{L1}=F_{H1}+\frac{(1-r_{L1})^2}{4}-\frac{(1-r_{H1})^2}{4}-\frac{1}{4}+\frac{(1-c)^2}{4}$$

$$=F_{H1}-\frac{(1-r_{H1})^2}{4}+\frac{(1-c)^2}{4} \qquad (8)$$

as the up-front fee aimed at the efficient firm. On the other hand, since (5) will be fulfilled as an equality, therefore, $F_{H1}=(1-c-r_{H1})^2/4$. The problem stated in (3)-(7) then becomes

$$\max_{r_{H1}} \Pi_1^{\mathrm{PH}}=\mu F_{L1}+(1-\mu)[F_{H1}+r_{H1}\cdot q_{H1}(r_{H1})]$$

$$= \left(\frac{1-c-r_{H1}}{2}\right)^2 + \mu\left[\frac{(1-c)^2}{4} - \frac{(1-r_{H1})^2}{4}\right] + (1-\mu)r_{H1}\frac{1-c-r_{H1}}{2}, \qquad (9)$$

and its resolution leads to the following result:

Lemma 2. *In the licensing-screening game, in period 1, the patent holder sets* $r_{H1} = \frac{\mu}{1-\mu}c$ *as the royalty rate aimed at the inefficient licensee. Besides,* $r_{L1} = 0$ *for the efficient licensee.*

Particularly, $r_{H1} = 0$ in the limit case where $\mu = 0$ (i.e., the patent holder is aware of the licensee's inefficiency). In this case, the contract offered to this (inefficient) user is reduced to a fixed fee equal to the entire surplus, as it should be under complete information. If $\mu > 0$, however, the royalty rate is positive and increases, both with μ, the probability of an efficient user in innovation marketing, and *c*, the marginal cost of production linked to a bad realization.[4]

Lemma 2 also states that when the patent holder offers the innovation under a separating contract, it is offered to both types of licensee, regardless of the patent holder's prior belief. In the equilibrium, the inefficient user is offered a contract formed by a mixture of a fixed fee, F_{H1} shown in Table 1, and a royalty rate r_{H1}, stated in Lemma 2 and summarized in Table 1. The efficient user, on the other hand, is offered the fee-only contract F_{L1} shown in Table 1.

Table 1. Equilibrium values of the first period in the licensing-screening game

$\tilde{c}$	r_1	F_1	q_1
0	0	$\frac{(1-\mu+\mu^2)c^2 - (2-\mu-\mu^2)c + 1 - \mu}{4(1-\mu)}$	$\frac{1}{2}$

[4] If μ=1, it is the case of a low-cost user for which r_{L1}=0, by virtue of the lemma.

c	$\frac{\mu}{1-\mu}c$	$\frac{1}{4}\left(\frac{1-\mu-c}{1-\mu}\right)^2$	$\frac{1-\mu-c}{2(1-\mu)}$

Under these circumstances, the expected revenue for the patent holder in period 1, $\Pi_{\text{scr}}^{\text{PH}} = \mu F_{L1} + (1-\mu)[F_{H1} + r_{H1} \cdot q_{H1}(r_{H1})]$, amounts to:

$$\Pi_{\text{scr}}^{\text{PH}} = \frac{(1-\mu+\mu^2)c^2 - (2-\mu-\mu^2)c + 1 - \mu}{4(1-\mu)}, \tag{10}$$

where subscript "scr" stands for the screening contract. Finally,

$$\Pi_{\text{scr}}^{\text{L}} = \frac{1}{4}\mu\frac{c[3-c-(3+c)\mu]}{1-\mu} \tag{11}$$

is the expected informational rent of the efficient licensee in period 1,[5] whereas it is $\Pi_{\text{scr}}^{\text{H}} = 0$ in case of an inefficient licensee.

3.3 The licensing-signaling game

In this case, at the beginning of period 1, the patent holder announces and commits itself to a fee F_1 and a per-unit royalty r_1 in exchange for innovation usage within this period. Contract (F_1, r_1) is the same for both licensee types, since the patent holder cannot distinguish between them in this period. The licensee accepts the offer and produces an output level q_1 according to its type. The patent holder observes this output level and, in a separating equilibrium, can infer the licensee's type. Thus, the second-period game becomes a complete information game. In this period, the patent holder commits itself to a

[5] Since μ<1-c implies μ(3+c)<3-c, this informational rent is positive in the entire region of parameters μ and c defined by Assumption 1.

new fixed fee F_2, according to the licensee's type.[6] Finally, the licensee selects its period 2 output q_2.

3.3.1 Period 2

In a separating equilibrium, the information gathered by the patent holder observing the firm's output in period 1 creates a complete-information game in period 2. So Lemma 1 still applies.

Note that the efficient firm will pay a higher fee than the inefficient firm. The efficient firm will then try to be perceived as inefficient, regardless of its true cost. Analysis of whether a low-cost firm could advantageously conceal its costs in period 1 and whether the two-period game admits equilibriums in which the foreseeable actions of the patent holder and a high-cost firm force the low-cost licensee to reveal its costs[7] is followed by the examination of separating equilibriums. It is assumed that, for the patent holder in period 2, after observing q_1, the period 1 licensee's production, the revised subjective probability of a licensee to be low-cost is zero if $q_1 = q_{H1}^s$ and unity otherwise, where q_{H1}^s is the period 1 output of a high-cost licensee in the (separating) equilibrium of the two-period signaling game.

By comparing the firm's profits in period 2, when it reveals and misrepresents its type, the following result arises.

Lemma 3. *In the licensing-signaling game, the licensee is interested in being perceived as an inefficient innovation user.*

[6] Due to complete information in period 2, the contract offered in that period only consists on a fixed fee.

[7] It is easy to show that, in this signalling game, there are no pooling equilibriums of interest for the players. For such equilibrium, an incomplete information game would be the game played in period 2 (because period 1 enables no new information on licensees' costs) and in period 1 (because playing an incomplete information game in period 2 means there is no reason not to maximize profits in period 1). But the incomplete information game *does* reveal the licensee's costs, contrary to the pooling assumption.

Proof: See the Appendix.

3.3.2 Period 1

To pay a lower fee in period 2, an efficient firm misrepresents itself as inefficient (as stated in Lemma 3) by producing the output level of an inefficient firm. Consequently, the inefficient firm, to distinguish itself from the efficient one, may be forced to produce, in period 1, no more than it would in the absence of signaling.

The period 2 net profit of the licensee when the patent holder believes its cost is *x*, while its true cost is *y*, is denoted by $\pi_2(x\,|\,y)$. Thus, the incentive compatibility condition for a low-cost licensee is

$$\pi_{L1}^{m} + \pi_2(0\,|\,0) \geq \pi_{L1}(q_{H1}^{s}) + \pi_2(c\,|\,0)\ , \qquad (12)$$

where π_{L1}^{m} represents its period 1 profit as a simple monopolist and $\pi_{L1}(q_{H1}^{s})$ its profit when it produces the output level of the inefficient firm. In turn, the incentive-compatibility condition for an inefficient licensee is

$$\pi_{H1}(q_{H1}^{s}) + \pi_2(c\,|\,c) \geq \pi_{H1}^{m} + \pi_2(0\,|\,c)\,, \qquad (13)$$

where $\pi_{H1}(q_{H1}^{s})$ denotes its period 1 profit when producing q_{H1}^{s}, the output showing its true type, and π_{H1}^{m} represents its period 1 profit when it represents itself as a high-cost firm and then produces like a simple (and myopic) inefficient monopolist, thus being perceived as a low-cost licensee and paying fee F_{L2} in exchange for the innovation in period 2. Analysis of conditions (12) and (13) leads to the following result.

Lemma 4. *The unique separating equilibrium of minimum cost of the licensing-signaling game is as follows:*

(i) *In period 1, the outputs of the low- and high-cost firm are* $q^s_{L1} = 1/2$ *and* $q^s_{H1} = [1 - \sqrt{c(2-c)}]/2$*, respectively. The patent holder charges the fee* $F^s_1 = [1 - (1-\mu)c(4 - c - 2\sqrt{c(2-c)})]/4$ *to both licensee types. There is no royalty payment.*

(ii) *The patent holder's subsequent beliefs are* $Prob(\tilde{c} = 0 \mid q_1 = q^s_{L1}) = 1$ *and* $Prob(\tilde{c} = c \mid q_1 = q^s_{H1}) = 1$

(iii) *In period 2, the outputs of the low- and high-cost firm are* $q_{L2} = 1/2$ *and* $q_{H2} = (1-c)/2$*, respectively. The patent holder sets the fee payment* $F_{L2} = 1/4$ *to the low-cost licensee and* $F_{H2} = (1-c)^2/4$ *to the high-cost one.*

Proof: See the Appendix.

Given that complete information holds after the period 1, the best an efficient licensee can do in period 1 is simply producing the output which maximizes its profit in the one-shot game, $q^s_{L1} = q^m_{L1}$. However, the inefficient firm, to distinguish itself from the efficient one, needs to produce, under incomplete information, a lower output level so as to maximize profits, $q^s_{H1} < q^m_{H1}$. Otherwise, its output would be mimicked by the efficient firm and a separating equilibrium would not hold. That is, signaling is costly in the entire (μ,c)-parameter space defined by Assumption 1, since it leads to distorted production in the high-cost licensee and, consequently, in the patent holder's incomes.

Another important feature is that, once again, royalties distort the licensee's behavior in period 1, so their inclusion in licensing contracts is unprofitable for the patent holder. Hence, the patent holder prefers to offer a fee-only contract under asymmetric information (Antelo, 2009). Table 2 shows a list of the values of the period 1 equilibrium of this game.

Table 2. Equilibrium values of the first period in the licensing-signaling game

$\tilde{c}$	r_1	F_1	q_1
0	0	$\frac{(1-\mu)c^2-(1-\mu)[4-2\sqrt{c(2-c)}]c+1}{4}$	$\frac{1}{2}$
c			$\frac{1-\sqrt{c(2-c)}}{2}$

To sum up, the (expected) licensing revenue accrued by the patent holder in period 1 amounts to:

$$\Pi_{\text{sig}}^{\text{PH}} = \frac{\mu+(1-\mu)[1-2c+\sqrt{c(2-c)}][1-\sqrt{c(2-c)}]}{4}, \tag{14}$$

where subscript "sig" denotes a signaling contract.

4. Screening vs. signaling

4.1 The patent holder

Comparison of the patent holder's revenue given in (10) and (14) renders the following result:

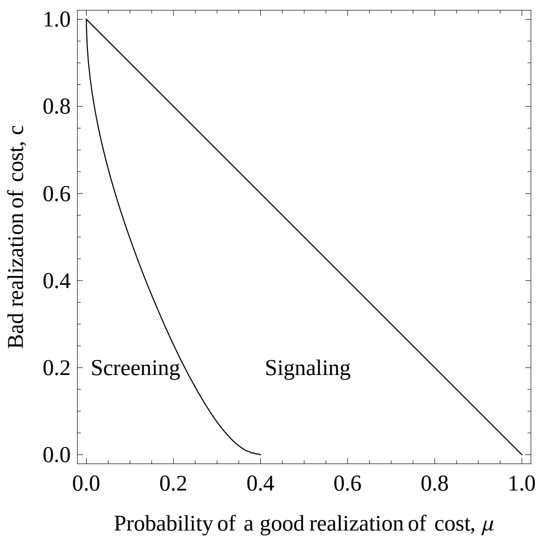
Proposition 1. *A screening contract provides the patentee with more licensing income than a signaling contract where parameters* μ *and c are such that*

$2\mu[5-2\sqrt{c(2-c)}]-7+c+4\sqrt{c(2-c)}+\sqrt{9-c[14-c-8\sqrt{c(2-c)}]}<0$. *Otherwise, a signaling contract is better for the patent holder.*

Proof: See the Appendix.

That is, a screening contract is better than a signaling contract only when both the parameter μ, the probability of an efficient firm exploiting the innovation, is below 0.4 and the parameter *c*, the size of the realization of high production cost, is low enough. Otherwise, if $\mu<0.4$ and *c* is high enough or $\mu>0.4$, regardless of the value adopted by parameter *c*, then a signaling contract allows the patent holder obtaining higher revenue than a screening contract. Figure 1, where the line plots the (μ,*c*)-locus defined by the condition in Proposition 1 as an equality, illustrates in the (μ,*c*)-parameter space the result of Proposition 1.

Figure 1. The patent holder's optimal form to obtain information



The explanation of this result is quite simple. In period 1, the efficient innovation user produces the same output level under screening and under signaling. In both cases, its production level is not distorted as compared to the profit-maximizing amount. The inefficient firm, however, under-produces in period 1 as compared to its profit-maximizing level. In the licensing-signaling game, the cause of under-production is endogenous: the inefficient firm tries to distinguish itself from the efficient firm and represents itself as inefficient, since the behaviour allows it paying a lower fee in period 2. Such productive distortion measures the cost of signaling and amounts to: $\nabla q_{\text{sig}} \equiv q_{H1}^{\text{m}} - q_{\text{sig}H1} = \frac{\sqrt{c(2-c)}-c}{2}$.

In the licensing-screening game, however, the cause of downward distortion on the inefficient firm's production is exogenous: the presence of a royalty rate in the licensing contract which increases the firm's marginal production cost. This under-production, as compared to the profit-maximizing amount, is given by $\nabla q_{\text{scr}} \equiv q_{H1}^{\text{m}} - q_{\text{scr}H1} = \frac{\mu}{2(1-\mu)}c$, being highly remarkable if μ>0.4 or μ<0.4, but *c* is large. In both cases, screening involves greater distortion on the inefficient firm's output than signaling. This fact reduces its profits under screening more than under signaling. Thus, the patent holder prefers a signaling to a screening contract.

4.2 Welfare considerations

To compare the outcomes of the screening and licensing games from a social perspective, expected aggregate welfare in period *t* is defined as the sum of expected consumer surplus, expected revenue for the patent holder, and expected profit for the licensee; namely $W_t = CS_t + \Pi_t^{\text{PH}} + \pi_t^{\text{L}}$, where superscripts PH and L stand for the patent holder and the efficient licensee, respectively.

Since both licensing games produce, in equilibrium, the same welfare level in period 2, comparison between them can be restricted to period 1. In the screening game, the level of welfare amounts to

$$W_{\text{scr}} = \frac{1}{8}\left[3-(6-4\mu)c+\frac{3-4\mu}{1-\mu}c^2\right] \tag{15}$$

and in the signaling game to

$$W_{\text{sig}} = \frac{1}{8}[3-6(1-\mu)c+(1-\mu)c^2+2(2c-1)(1-\mu)\sqrt{c(2-c)}]. \tag{16}$$

Thus, the following result can be stated accordingly:

Proposition 2. *From a social perspective, a screening contract is superior to a signaling contract, except for parameters* μ *and c fulfilling* $c > \frac{2(1-\mu)^2}{1+(1-\mu)^2}$*; then, a signaling contract creates greater welfare.*

Proof: See the Appendix.

From a social viewpoint, a screening or separating contract is superior to a signaling contract in almost all the (μ,*c*)-region *R* of parameters defined by Assumption 1. The explanation is as follows. Under either screening or signaling the amount produced in period 1 by the efficient licensee is not distorted as compared to the profit-maximizing amount. Contrariwise, the output of the inefficient licensee is distorted downward as compared to the profit-maximizing amount. Although the distortion under a signaling contract may be lower than under a screening contract (see Proposition 1), the former motivates a welfare loss, since both the firm's profit (or the patent holder’s licensing income) and consumer surplus in period 1 decrease. Distortion due to a screening contract, however, causes (a welfare loss but, especially) welfare re-distribution: it reduces the patent holder's income and consumer surplus in period 1, but allows the efficient firm obtaining informational rents in this period. Thus, from a social viewpoint (not only the patent holder but also consumers and the innovation user are considered), a screening contract is generally superior.

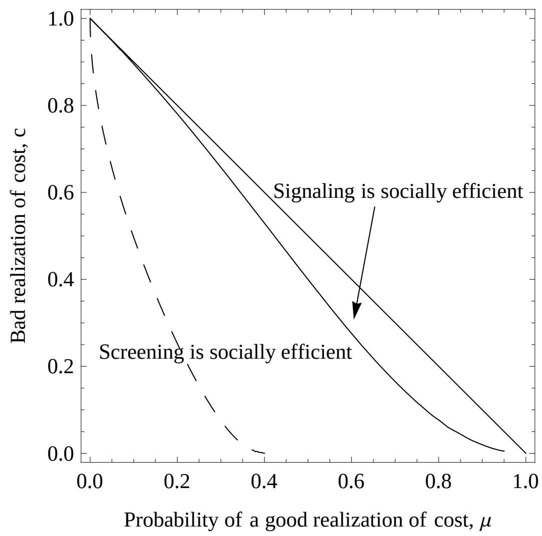
Nevertheless, there is just a small *c*-interval at the high border of region *R* which fulfilling

$$\frac{2(1-\mu)^2}{1+(1-\mu)^2} < c < 1-\mu \,, \qquad (17)$$

in which the output distortion of the inefficient licensee is more pronounced under screening than under signaling. Consequently, informational rents for the efficiency licensee decrease to the point that the expected social welfare is lower under a screening than a signaling contract.

The result of Proposition 2 is illustrated in Figure 2, where the dashed line plots the (μ,*c*)-locus which separates the region where the patent holder prefers a signaling contract and that where a screening contract is preferred. The solid line, on the other hand, plots the condition defined by $c - 2(1-\mu)^2 / [1+(1-\mu)^2] = 0$ and separates the (μ,*c*)-region, where a separating contract is socially optimal, from the (μ,*c*)-region, where a signaling contract is socially preferable.

Figure 2. The social impact of screening and signaling



Comparison of Propositions 1 and 2 allows us concluding that when the patent holder either screens the licensee or induces signaling and the parameter cost *c* is high enough, private and social incentives are aligned.

5. Conclusions

This paper studies licensing from a patent holder, which has no manufacturing capacity for innovation exploitation, to a firm able to market the innovation. The patent lasts for two periods and the potential user disposes of private information on the market value of such innovation and thus give rise to opportunism problems. To alleviate the adverse selection problem, the patent holder may offer a separating contract which leads the licensee to disclose its production costs (i.e., screening) or may allow the user signaling itself through the produced output (i.e., signaling). Two agents—the patent holder and the buyer of the patent—interact in this two-period model. The market demand for final product is common knowledge, but both agents have different information on the efficiency level of the user in marketing the innovation: while it is privately known by the firm, it remains unknown for the patent holder. Furthermore, both players are risk-neutral and there is no discount factor.

In this context, if the patent holder chooses a (screening) separating contract to sell the innovation, the optimal menu of contracts in period 1 consists on a fixed fee for the efficient innovation user and a two-part tariff for the inefficient user. The efficient firm does not distort its production level as compared to the profit-maximizing amount. However, the inefficient firm produces less than the corresponding profit-maximizing level due to the increased production cost caused by the imposed royalty. If, on the other hand, the patent holder licenses the innovation by allowing the licensee signaling its cost through the produced amount in period 1, there is a unique separating equilibrium in which the period 1 contract is formed by the same fixed fee for both firm types. In this case, the firm which becomes efficient in marketing the innovation does not distort its production in period 1, but the inefficient user strategically reduces its production level so as to represent itself as inefficient and thus pay a lower fee in period 2.

Comparison of screening and signaling contracts suggests that the patent holder finds more profitable to offer a screening contract if the firm is likely to be inefficient, but the difference in production costs between the efficient and inefficient firm is not very large. In this case, signaling involves little cost. Otherwise (i.e., when the firm is very likely to become inefficient and the difference in production costs is very high, or when the firm is very likely to become efficient regardless of cost difference), a signaling contract is then better than a screening contract. For the licensee, in turn, a screening contract is unambiguously the best option, since it only benefits from the licensing-screening game. Finally, consumers generally prefer screening to signaling. There is, however, a little region of parameters defined by a sufficiently large difference in costs where a signaling contract increases consumers' utility relative to a screening contract.

From a social viewpoint, a screening contract is generally superior to a signaling contract to sell the innovation, except for a little region of parameters, since signaling involves lower social loss. The intuition of this result relies on the fact that the efficient innovation user obtains some informational rents under a screening contract, but not under a signaling contract. Moreover, the more likely the firm is to become efficient and the higher production cost difference is, the higher the magnitude of such rents is. This finding allows concluding that social preferences are not always aligned with the licensor opinion.

Some model assumptions could be easily removed to examine the robustness of the results. For instance, the consideration of a discount factor different than one allows concluding that the region in which the patent holder prefers a signaling contract increases when compared to the case of no discount factor. Thus, a signaling contract is more likely to emerge in licensing schemes as interest rates increase, since signaling cost decreases with discount factor. Hence, the patent holder would never resort to a screening contract to sell the innovation for a sufficiently high discount.[8] The model could be also examined in the light of risk aversion or the consideration of more than one firm as potential licensees of the innovation so as to assess the robustness of the results. These issues remain for future research.

[8] Indeed, the separating equilibrium in the signaling game becomes costless for a high enough discount factor.

Appendix A

Proof of Lemma 3: Since complete information characterizes period 2, the optimal licensing contract for this period is a fee-only contract. Denoted by $\pi_2(x\,|\,y)$, the period 2 net profit of the licensee if the patent holder believes its cost was *x* but really was *y*. Thus, if *x*=*c*, but *y*=0, in period 2 the patent holder offers the fee-alone contract given by $F_{H2}=(1-c)^2/4$. Consequently, the net profit of the licensee amounts to: $\pi_2(c\,|\,0)=\pi_2(0\,|\,0)-F_{H2}=c(2-c)/4$. A similar reasoning shows that: $\pi_2(0\,|\,c)=\pi_2(c\,|\,c)-F_{L2}=-c(2-c)/4$. Comparison of profit $\pi_2(c\,|\,0)$ with $\pi_2(0\,|\,0)=0$, and profit $\pi_2(0\,|\,c)$ with $\pi_2(c\,|\,c)=0$ shows that $\pi_2(c\,|\,0)>\pi_2(0\,|\,0)$ and $\pi_2(0\,|\,c)<\pi_2(c\,|\,c)$. This proves the result of the lemma.

Proof of Lemma 4: The best a low-cost firm can do, in the separating equilibrium in period 1, is producing

$$q_{L1}^{s}=q_{L1}^{m}=\frac{1-r_1}{2}, \tag{A1}$$

where superscripts *s* and *m* stand for signaling and monopoly regimes, respectively, and r_1 is the royalty rate imposed by the patent holder. On the other hand, spelling out Equations (12) and (13) shows that

$$\frac{(1-r_1)^2}{4}\geq(1-r_1-q_{H1}^{s})\,q_{H1}^{s}+\frac{c(2-c)}{4} \tag{A2}$$

and

$$(1-c-r_1-q_{H1}^{s})\,q_{H1}^{s}\geq\frac{(1-c-r_1)^2}{4}-\frac{c(2-c)}{4}, \tag{A3}$$

which are simultaneously fulfilled by any output $q_{H1}^{s}\in[a^{-},b^{-}]$, where a^{-} and b^{-} are the smaller roots of the quadratic equations obtained by taking (A2) and (A3), respectively, as equalities. That is, $b^{-}=[1-r_1-\sqrt{c(2-c)}]/2$ and

$a^{-}=[1-c-r_1-\sqrt{c(2-c)}]/2$, with $a^{-}<b^{-}$. Taking into account that $b^{-}<(1-r_1-c)/2\equiv q_{H1}^{m}$, the period 1 outputs which form part of the separating equilibrium of minimum cost are $q_{H1}^{s}=[1-r_1-\sqrt{c(2-c)}]/2$ for the high-cost licensee and $q_{L1}^{s}=(1-r_1)/2$ for the low-cost licensee. Given these outputs, the patent holder sets the period 1 royalty r_1 to maximize its revenue from granting a license in this period—i.e.

$$\max_{r_1}\ \mu\left(\frac{1-r_1}{2}\right)^2+(1-\mu)\left(1-c-r_1-\frac{1-r_1-\sqrt{c(2-c)}}{2}\right)\frac{1-r_1-\sqrt{c(2-c)}}{2}$$

$$+\mu r_1\frac{1-r_1}{2}+(1-\mu)r_1\frac{1-r_1-\sqrt{c(2-c)}}{2}.$$

(A4)

Finally, solving the first-order condition of problem (A4) enables $r_1=(1-\mu)[c-\sqrt{c(2-c)}]$, which is negative, since c<1. Given the concavity of the objective function of the problem (A4), the best the patent holder can do is setting a zero royalty rate. Conditions (A1), (A2) and (A3) then become

$$q_{L1}^{s}=q_{L1}^{m}=\frac{1}{2} \tag{A5}$$

$$\frac{1}{4}\geq(1-q_{H1}^{s})\,q_{H1}^{s}+\frac{c(2-c)}{4}, \tag{A6}$$

and

$$(1-c-q_{H1}^{s})\,q_{H1}^{s}\geq\frac{(1-c)^2}{4}-\frac{c(2-c)}{4}, \tag{A7}$$

respectively. Conditions (A6) and (A7), considered as equalities, have roots given by $q_{H1}^{s}=[1\pm\sqrt{c(2-c)}]/2$ and $q_{H1}^{s}=[1-c\pm\sqrt{c(2-c)}]/2$, respectively. Thus, both conditions (A6) and (A7) are simultaneously satisfied by any output $q_{H1}^{s}\in[v^{-},z^{-}]$, where $v^{-}=[1-c-\sqrt{c(2-c)}]/2$ and $z^{-}=[1-\sqrt{c(2-c)}]/2$, being that $v^{-}<z^{-}$. Taking into

account that $z^{-}=[1-\sqrt{c(2-c)}]/2 < (1-c)/2 \equiv q_{H1}^{m}$, the period 1 outputs forming part of the unique separating equilibrium of minimum cost are $q_{H1}^{s}=z^{-}$ for the high-cost firm and $q_{L1}^{s}=q_{L1}^{m}$ for the low-cost firm. This completes the proof of the proposition.

Proof of Proposition 1: The difference between the period 1 licensing income the patent holder reaps under a screening contract, $\Pi_{\mathrm{scr}}^{\mathrm{PH}}$, and that obtained under a signaling contract, $\Pi_{\mathrm{sig}}^{\mathrm{PH}}$, amounts to

$$\Pi_{\mathrm{scr}}^{\mathrm{PH}}-\Pi_{\mathrm{sign}}^{\mathrm{PH}}=c\frac{2-2\sqrt{c(2-c)}-\mu\{7-c-4\sqrt{c(2-c)}-\mu[5-2\sqrt{c(2-c)}]\}}{4(1-\mu)}. \quad \text{(A8)}$$

The sign of (A8) depends on the sign of the numerator. This expression, which can be rewritten as $[5-2\sqrt{c(2-c)}]\mu^{2}-[7-c-4\sqrt{c(2-c)}]\mu+2[1-\sqrt{c(2-c)}]$, is a second-degree and convex function of μ, whose roots are

$$\mu=\frac{7-c-4\sqrt{c(2-c)}\pm\sqrt{9-c[14-c-8\sqrt{c(2-c)}]}}{2[5-2\sqrt{c(2-c)}]}. \quad \text{(A9)}$$

The highest root of the two given in (A9), however, verifies that

$$\frac{7-c-4\sqrt{c(2-c)}+\sqrt{9-c[14-c-8\sqrt{c(2-c)}]}}{2[5-2\sqrt{c(2-c)}]}>1-c. \quad \text{(A10)}$$

Hence, it is not compatible with Assumption 1. Thus, the only relevant root is the lowest one, and expression (A8) becomes positive as long as

$$\mu<\frac{7-c-4\sqrt{c(2-c)}-\sqrt{9-c[14-c-8\sqrt{c(2-c)}]}}{2[5-2\sqrt{c(2-c)}]}. \quad \text{(A11)}$$

In this case, the patent holder obtains higher income in period 1 under a screening contract than under a signaling contract. On the contrary, if condition

(A11) is fulfilled in the opposite sense, signaling is then superior to screening. This completes the proof of the proposition.

Proof of Proposition 2: Under a screening contract, the expected welfare in period 1 amounts to

$$W_{\text{scr}} = CS_{\text{scr}} + \Pi_{\text{scr}}^{\text{PH}} + \pi_{\text{scr}}^{\text{L}}$$

$$= \frac{1}{8}\left[\mu + (1-\mu)\left(1 - \frac{1}{1-\mu}c\right)^2\right]$$

$$+ \frac{1}{4}\left(1 - \frac{1}{1-\mu}c\right)^2 + \frac{1}{4}\mu\left[1 - c - \left(1 - \frac{\mu}{1-\mu}c\right)^2 + 2\left(1 - \frac{1}{1-\mu}c\right)c\right]$$

$$+ \frac{1}{4}\mu\left[\left(1 - \frac{\mu}{1-\mu}c\right)^2 - \left(1 - \frac{1}{1-\mu}c\right)^2 + c\right] \qquad \text{(A12)}$$

and under a signaling contract, it amounts to

$$W_{\text{sig}} = CS_{\text{sig}} + \Pi_{\text{sig}}^{\text{PH}}$$

$$= \frac{1}{8}[\mu + (1-\mu)(1 - \sqrt{c(2-c)})^2]$$

$$+ \left[\frac{1}{4}\mu + (1-\mu)\frac{1 - 2c + \sqrt{c(2-c)}}{2}\,\frac{1 - \sqrt{c(2-c)}}{2}\right]$$

(A13)

Comparison of (A12) and (A13) yields

$$\text{Sign}\,(W_{\text{scr}} - W_{\text{sig}}) = \text{Sign}\,[(2 - 2\mu - \mu^2)c^2 - 2\mu(1-\mu)c - 2(2c-1)(1-\mu)^2\sqrt{c(2-c)}] \qquad \text{(A14)}$$

and solving the equation

$$(2 - 2\mu - \mu^2)c^2 - 2\mu(1-\mu)c - 2(2c-1)(1-\mu)^2\sqrt{c(2-c)} = 0 \qquad \text{(A15)}$$

yields the roots: $c = 0$, $c = \frac{2(1-\mu)^2}{1+(1-\mu)^2}$,

$$c = \frac{7 - 16\mu + 9\mu^2 - \sqrt{9 - 40\mu + 66\mu^2 - 48\mu^3 + 13\mu^4}}{10 - 26\mu + 17\mu^2},$$

and

$$c = \frac{7 - 16\mu + 9\mu^2 + \sqrt{9 - 40\mu + 66\mu^2 - 48\mu^3 + 13\mu^4}}{10 - 26\mu + 17\mu^2}.$$

The proof of the proposition is completed by inspection of these roots.

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