Theoretical and Applied Economics
Volume XVIII (2011), No. 10(563), pp. 5-22

Optimal Licensing Contracts with Three Innovation Types

Daniela MARINESCU
Bucharest Academy of Economic Studies
danielamarinescu@hotmail.com, daniela.marinescu@csie.ase.ro
Dumitru MARIN
Bucharest Academy of Economic Studies
dumitrumarin@hotmail.com, dumitru.marin@csie.ase.ro

Abstract. *In the paper we analyze the features of the optimal licensing contracts in the situation of asymmetric information between the license's owner and the potential buyer. The approach is based on a classical model of adverse selection first proposed by Macho-Stadler and Perez-Castrillo (1991) and solved in an alternative way, using the informational rents as variables, by Marinescu and Marin (2011). Their model is extended in the present paper by assuming that the adverse selection parameter can have one of three possible values (corresponding to three possible types of innovations).*

Keywords: optimal contract; innovation; adverse selection; informational rents.

JEL Codes: C61, D82, D86.
REL Code: 17C.

Introduction

Competition plays a very important role for the firms' existence on almost every market. One of the main goals of any productive firm is finding new production technologies generating lower production costs, but high qualitative goods or services and yielding to efficient results. The firms pay a special attention to the development of new patents or innovations yielding to a higher competitive position on the market.

Usually, a licensing contract is based on a fixed fee (and this fee is independent of the output produced or the activity) and a variable fee (royalty), dependent on the volume of output. Although the optimality of licensing contracts has been considerable studied in the last twenty years, there is not a general conclusion about the form of these contracts. The terms of licensing contracts depend on many factors such as: if the innovator (the licensor) competes with the innovation in the same market as the potential buyer, the number of firms competing for the innovation (potential buyers of the innovation), the seller's possibility to verify and to monitor the buyer after selling the patent or risk sharing between the two contractual partners (the seller and the buyer).

In the last twenty years, several authors tried to determine, on theoretical reasons, the optimal form of licensing contracts and to explain the necessity of including some variable fees a license contract. In the literature, the initial papers focused on situations with symmetric information between the licensor and the licensee: Katz and Shapiro (1985, 1986), Gallini (1984), Kamien and Tauman (1986). With the rapid development of the incentive theory in the last twenty years, many theoretical studies pointed out that the presence of asymmetric information between the licensor and the licensee influenced the form of licensing contracts: Gallini and Wright (1990), Macho-Stadler and Perez-Castrillo (1991), Begg (1992), Erutku et al. (2008), Antelo (2009), Marinescu and Marin (2011).

In their paper, Gallini and Wright (1990) analyse the consequences of seller's private information on the optimality of contracts and they show that the high quality innovations are signalled through two-part contracts (a fixed fee and a variable fee). Macho-Stadler and Perez-Castrillo (1991) derive the features of optimal licensing contracts in two different situations of asymmetric information between the partners: signalling (the Principal-the seller has some private information and can signal the high quality on the patent through contracts based on royalties) and screening (the Agent-the buyer has some private information about the true value of the patent and the contracts must be based only on fixed fees). Begg (1992) shows that a contract based on royalties are more efficient than a licence contract based on fixed fee, due to the existence of a separating equilibrium of the game he analysed. In another theoretical study on the design of optimal contracts in the situation of incomplete information, Erutku et al. (2008)

consider that the contracts based only on royalties are suboptimal from the buyer's perspective since there is always a two part contract dominating the contract based on royalties. Antelo (2009) analyses in a signalling game the effects of asymmetric information (the contract duration and the choice of the royalties) on the design of royalties-only contracts. Crama et al. (2008) study the form of optimal licensing contracts when the buyer's evaluation of innovation represents incomplete information; they show that the presence of moral hazard and adverse selection can yields to a higher loss.

There are not so many empirical studies about the optimal terms of licensing contracts and the results don't confirm all the features generated in theoretical studies. Some interesting analysis belong to Rostocker (1983), Taylor and Silberstone (1973), Grindley and Nickerson (1996) (chemical industry), Grindley and Teece (1997) (electronics industry), Macho-Stadler et al (1996), Anand et al (2000) (cross industries analysis), Jensen and Thursby (2001), Mukherjee et al (2008), Nagaoka (2009).

The paper is organized as follows. In Section 1 we briefly present the model of Macho-Stadler and Perez-Castrillo. In Section 2 we propose an extension of this model to the case where the potential buyer can have one of three possible types (here represented by the average production cost). We solve the extended model in the next section. In the Principal's optimization problem, we use the informational rents as variables which permit us to interpret the features of the optimal licensing contracts in terms of the problems with asymmetry of information between the contractual partners. Section 4 gives an example of deriving the optimal contracts and discusses possible interpretations of the results. A final section concludes the article.

1. The standard model

In their paper, Macho-Stadler and Perez-Castrillo (1996) analysed two types of problems with informational asymmetry between the seller (the owner of a patent) and the buyer (a firm who's intention is to use the patent) of one innovation (license). The first problem corresponds to a classical signalling problem where the seller knows better than the buyer the quality of innovation. The second problem, where the buyer has an informational advantage (private information), corresponds to an adverse selection problem. This last type of problem is described in our paper.

We assume that a research institute owns a patent (innovation) and it can't obtain profit directly, but only through a licensing contract. We will refer further at this institute as being the Principal.

On the other hand, the Agent is a monopolist (a firm) having a constant average production cost c^0, so that the total cost of production is given by $c^0 \times Q$.

Definition 1. A licensing contract in the situation of symmetric information is a pair (F, ε), where:

F represents the amount paid by the monopolist when signing the contract (this is usually referred as a *fixed fee*);

ε is the amount paid by the Agent to the Principal for each unit produced by the firm using the patent (this is usually referred as a variable fees or royalties).

In the new situation – after buying the license, the average production cost becomes lower than c^0, such that we have $c < c^0$.

We assume that the market demand function for the good produced by the monopolist is given by $D(P)$ and the monopoly price is denoted by $P^m(x)$. Then, for each level of the average cost *x*, the firm's profit function is denoted by $\pi^m(x)$. We give, without proof (the interested reader finds the proof in Marinescu and Marin (2011)), the following proposition:

Proposition 1. The profit function satisfies:

$$\frac{d\pi^m(x)}{dx} = -D\left(P^m(x)\right)$$

1.1. The optimal contract in the situation of symmetric information

First suppose that there is no asymmetry of information between the Principal and the Agent. This corresponds to the situation where both the seller and the buyer (of the patent) know the true value of the innovation.

The Principal's problem is to maximize the total profit subject to Agent's participation constraint (showing that he is willing to pay no more than the profit excess).

We use the following notation:

$$D^m(x) = D\left(P^m(x)\right)$$

The Principal's optimization problem to be solved is written as:

$$\underset{F,\varepsilon}{(\max)}\left[F + \varepsilon D^m(c+\varepsilon)\right]$$

$$s.r.$$

$$F \le \pi^m(c+e) - \pi^m(c^0)$$

$$F \ge 0$$

$$\varepsilon \ge 0$$

The optimal solution of this problem is given in the following theorem (its proof is given in details in Marinescu and Marin (2011)):

Theorem 1. In the case of symmetric information, the optimal licensing contract (the first best solution) in the sense of *Definition 1* is $(\tilde{F}, \tilde{\varepsilon} = 0)$, with $\tilde{F} = \pi^m(c) - \pi^m(c^0)$.

In such a situation, the optimal licensing contract is based only on a fixed fee, which is exactly equal to the buyer's profit excess and the Agent's production is efficient.

1.2. The optimal contract in the situation of asymmetric information

With asymmetry of information, the Agent has private information (hidden information) and knows better than the Principal how important the innovation is. In some situations, the asymmetry of information consists in a better knowledge of the buyer related to the demand function for the output he produces or related to the production technology impact and the real value of the innovation. These situations are more probable when the patent's owner doesn't act on the industry or on the respective product market.

In our model, the Principal (the owner of the license) considers that the Agent's evaluation is one of two types – the type G (good) or the type B (bad), and having the corresponding average cost $c^G < c^0$ and $c^B < c^0$ respective, with $c^G < c^B$. The probability the Principal believes that the innovation has the type G is denoted by γ.

With symmetric information, the Principal, knowing the Agent's type, makes a contractual offer consisting in a contract based only on fixed fee and without variable fees. The optimal contract is represented by:

$(\tilde{F}^G, \tilde{\varepsilon}^G = 0)$, with $\tilde{F}^G = \pi^m(c^G) - \pi^m(c^0)$, if the Agent's type is G

and

$(\tilde{F}^B, \tilde{\varepsilon}^B = 0)$, cu $\tilde{F}^B = \pi^m(c^B) - \pi^m(c^0)$, if the Agent's type is B.

Without knowing the innovation type, it is optimal for the Principal to propose a menu of contracts, one contract for each type of Agent, hoping that each type chooses the contract designed for him. The features of the optimal menu of contracts are summarized in the next theorem:

Theorem 2. The optimal contract in the situation of *adverse selection* (the second best solution) $\left((\overline{F}^G, \overline{\varepsilon}^G), (\overline{F}^B, \overline{\varepsilon}^B)\right)$ satisfies the following:

$$\overline{F}^G < \tilde{F}^G,\ \overline{\varepsilon}^G = \tilde{\varepsilon}^G = 0$$

and

$$\overline{F}^B < \overline{F}^G,\ \overline{\varepsilon}^B > 0.$$

Before going further, we make some remarks regarding the theorem's results:

A. The contract designed for the firm with high evaluation (type G) is completely based on a fixed fee $\overline{F}^G$ lower than the fixed fee corresponding to the situation of symmetric information (the first best solution). We have therefore, $\overline{\varepsilon}^G = 0 = \tilde{\varepsilon}^G$.

This contract gives to the Agent of type G a positive informational rent $\overline{U}^G = \phi(\overline{\varepsilon}^B)$.

B. The contract designed for the low evaluation (type B) generates the same profit as the profit obtained without using the new technology. This second best contract is based on two parts: a fixed fee $\overline{F}^B$ and a variable fee, $\overline{\varepsilon}^B > \tilde{\varepsilon}^B = 0$. With this contract the Agent gets no informational rent.

2. The extended model: three types of innovation

Coming back to the situation of asymmetric information, we now suppose that the Principal believes that the innovation generates a reduction in the average production cost such that there are three possible values of innovation:

- the type G with the probability $\gamma^G > 0$,
- the type M with the probability $\gamma^M > 0$ and
- the type B with the probability $\gamma^B > 0$, where $\gamma^G + \gamma^M + \gamma^B = 1$.

We consider the variables $e^G = \varepsilon^G + c^G$, $e^M = \varepsilon^M + c^M$, $e^B = \varepsilon^B + c^B$, where:

$c^G < c^M < c^B < c^0$ and $\Delta\theta = c^B - c^M = c^M - c^G$.

As we have already seen, under complete information, when the Principal makes a contractual offer to the Agent, the optimal contract is based only on fixed fees and takes the following form:

$(\tilde{F}^G, \tilde{\varepsilon}^G = 0)$, with $\tilde{F}^G = \pi^m(c^G) - \pi^m(c^0)$, for the type G,

$(\tilde{F}^M, \tilde{\varepsilon}^M = 0)$, with $\tilde{F}^M = \pi^m(c^M) - \pi^m(c^0)$, for the type M

and

$(\tilde{F}^B, \tilde{\varepsilon}^B = 0)$, cu $\tilde{F}^B = \pi^m(c^B) - \pi^m(c^0)$, for the type B.

Under asymmetric information, it is optimal for the Principal to propose a menu of contracts, one contract for each type of Agent, such that each type chooses exactly the contract designed for him. The menu of contracts consists in the set of pairs fixed fee-variable fee $\{(F^G, \varepsilon^G), (F^M, \varepsilon^M), (F^B, \varepsilon^B)\}$.

The Principal's objective function (maximizing his expected profit) is now written as:

$$\max_{(F^G,\varepsilon^G),(F^M,\varepsilon^M),(F^B,\varepsilon^B)}\{\gamma^G\left[F^G+\varepsilon^G D^m\left(\varepsilon^G+c^G\right)\right]+\gamma^M\left[F^M+\varepsilon^M D^m\left(\varepsilon^M+c^M\right)\right]+$$
$$+\gamma^B\left[F^B+\varepsilon^B D^m(c^B+\varepsilon^B)\right]\}$$

When solving the model, we use as variables the informational rents, defined below.

Definition 2. The expressions:

$U^G=\pi^m(c^G+\varepsilon^G)-F^G-\pi^m(c^0)$,

$U^M=\pi^m(c^M+\varepsilon^M)-F^M-\pi^m(c^0)\geq 0$

and $U^B=\pi^m(c^B+\varepsilon^B)-F^B-\pi^m(c^0)$

are the *informational rents for each type of innovation G, M,* and *B*, respectively.

Within the set of possible contracts to be proposed by the Principal we have to pay attention to those contracts to be accepted by the Agent.

Definition 3. A menu of contracts $\{(F^G,\varepsilon^G),(F^M,\varepsilon^M),(F^B,\varepsilon^B)\}$ is *feasible* if it satisfies the following participation constraints:

$$U^G=\pi^m(c^G+\varepsilon^G)-F^G-\pi^m(c^0)\geq 0 \qquad (1)$$

$$U^M=\pi^m(c^M+\varepsilon^M)-F^M-\pi^m(c^0)\geq 0 \qquad (2)$$

$$U^B=\pi^m(c^B+\varepsilon^B)-F^B-\pi^m(c^0)\geq 0 \qquad (3)$$

Each of the above constraints shows that the contract assigned to each type of Agent yields a profit higher than the profit obtained without using the innovation.

Furthermore, for a contract to be accepted it must satisfy the incentive compatibility constraints, meaning that each Agent selects the contract designed for him.

The incentive compatibility constraint for the type G (imposing not to choose the contract of type *M*), expressed in terms of informational rents is:

$$U^G=\pi^m(c^G+\varepsilon^G)-F^G-\pi^m(c^0)\geq\pi^m(c^G+\varepsilon^M)-F^M-\pi^m(c^0)=$$
$$=\pi^m\left(c^M+\varepsilon^M\right)-F^M-\pi^m\left(c^0\right)+\pi^m\left(c^G+\varepsilon^M\right)-\pi^m\left(c^M+\varepsilon^M\right)=$$
$$=U^M+\pi^m\left(c^M+\varepsilon^M+c^G-c^M\right)-\pi^m\left(c^M+\varepsilon^M\right)$$

In what follows we use the notation $f(e) = \pi^m(e) - \pi^m(e + \Delta\theta)$. The function $f(\cdot)$ has the following properties:

i) $f(e) > 0, \forall e \geq 0$

ii) $f'(e) < 0, \forall e \geq 0$

With the above notation, the incentive compatibility constraint can be rewritten as:

$$U^G \geq U^M + f(e^M - \Delta\theta) \tag{4}$$

Similarly, the other compatibility constraint for the type G imposing not to choose the contract of type *B* is:

$$U^G \geq \pi^m(c^G + \varepsilon^B) - F^B - \pi^m(c^0)$$

or

$$U^G \geq U^B + f(e^B - 2\Delta\theta) + f(e^B - \Delta\theta) \tag{5}$$

In a similar manner we can express the incentive compatibility constraints for the type M:

$$U^M \geq \pi^m(c^M + \varepsilon^G) - F^G - \pi^m(c^0)$$

or

$$U^M \geq U^G - f(e^G) \tag{6}$$

and

$$U^M \geq \pi^m(c^M + \varepsilon^B) - F^B - \pi^m(c^0)$$

or

$$U^M \geq U^B + f(e^B - \Delta\theta) \tag{7}$$

For the type B, we also have the following constraints:

$$U^B \geq U^G - f(e^G) - f(e^G + \Delta\theta) \tag{8}$$

$$U^B \geq U^M - f(e^M) \tag{9}$$

We can classify the incentive compatibility constraints into two categories (Laffont and Martimort, 2002, pp. 86-90): local and global incentive constraints. Hence, the constraints (4) and (7) are upward local incentive constraints (ULIC), while the constraint (5) is an upward global incentive constraint (UGIC); the constraints (6) and (9) are downward local incentive constraints (DLIC), while the constraint (8) is a downward global incentive constraint (DGIC).

Definition 4. A menu of feasible contracts $((F^G, \varepsilon^G), (F^B, \varepsilon^B))$ is *incentive feasible* if it satisfy also the following incentive compatibility constraints:

$$U^G \geq U^M + f\left(e^M - \Delta\theta\right) \qquad (10) \quad \text{ULIC}$$
$$U^M \geq U^B + f\left(e^B - \Delta\theta\right) \qquad (11) \quad \text{ULIC}$$
$$U^G \geq U^B + f\left(e^B - 2\Delta\theta\right) + f\left(e^B - \Delta\theta\right) \qquad (12) \quad \text{UGIC}$$
$$U^M \geq U^G - f\left(e^G\right) \qquad (13) \quad \text{DLIC}$$
$$U^B \geq U^M - f\left(e^M\right) \qquad (14) \quad \text{DLIC}$$
$$U^B \geq U^G - f\left(e^G\right) - f\left(e^G + \Delta\theta\right) \qquad (15) \quad \text{DGIC}$$

Note that the menu is feasible, so it satisfies the participation constraints.

3. Solving the extended model

Having all the constraints defined, the Principal's optimization problem is in fact a nonlinear optimization problem with six inequality constraints and the sign constraints for six variables (informational rents and variable fees). The major technical difficulty in solving the problem is generated by the huge number of constraints, but also the number of variables. Before solving it, we try to reduce it, using the following remarks.

Proposition 1. (The implementability condition): If the set of feasible solutions is nonempty, then $\varepsilon^G \leq \varepsilon^M \leq \varepsilon^B$.

Proof

We add the constraints (10) and (13) and we get:

$$f\left(e^G\right) \geq f\left(e^M - \Delta\theta\right)$$

and adding the constraints (11) and (14) we get:

$$f\left(e^M\right) \geq f\left(e^B - \Delta\theta\right)$$

From the above two relations it follows that:

$$e^G \leq e^M - \Delta\theta \text{ and } e^M \leq e^B - \Delta\theta$$

or

$$e^G - c^G \leq e^M - c^M \leq e^B - c^B$$

and this yields to:

$$\varepsilon^G \leq \varepsilon^M \leq \varepsilon^B.$$

More than this result, the condition $e^M \leq e^B - \Delta\theta$ can be rewritten as:

$$e^M - \Delta\theta \leq e^B - 2\Delta\theta$$

and so the upward global incentive constraint (12) is implied by the upward local incentive constraints. Therefore, we can ignore it when solving the Principal's problem.

We also ignore for a while the downward constraints and we check later that the solution derived for the reduced optimization program (without the constraints (13), (14) and (15)) satisfies also these constraints.

The Principal's objective function, expressed in terms of informational rents becomes:

$$\max_{\varepsilon^G,\varepsilon^M,\varepsilon^B,U^G,U^M,U^B}\{\gamma^G\left[\pi^m(c^G+\varepsilon^G)+\varepsilon^G D^m\left(\varepsilon^G+c^G\right)\right]+$$
$$+\gamma^M\left[\pi^m\left(c^M+\varepsilon^M\right)+\varepsilon^M D^m\left(c^M+\varepsilon^M\right)\right]+$$
$$+\gamma^B\left[\pi^m\left(c^B+\varepsilon^B\right)+\varepsilon^B D^m\left(c^B+\varepsilon^B\right)\right]-$$
$$-\left[\gamma^G U^G+\gamma^M U^M+\gamma^B U^B\right]$$

If we add the upward local incentive constraints (10) and (11):

$U^G \geq U^M + f\left(e^M-\Delta\theta\right)$ and $U^M \geq U^B + f\left(e^B-\Delta\theta\right)$

and the non-negativity constraints: $U^G \geq 0,\ \ U^M \geq 0$ and $U^B \geq 0$, we get a reduced form of the Principal's optimization problem.

We can reduce more the above problem (we reduce the number of optimization variables) using the following result:

Proposition 2. In the Principal's optimization problem, at the optimum, we have:

$U^B = 0$, $U^M = f\left(e^B-\Delta\theta\right)$ and $U^G = f(e^B-\Delta\theta)+f(e^M-\Delta\theta)$.

Proof

Suppose that $U^B > 0$ and let $u > 0$ be a small real value such that $U^B - u \geq 0$. Then the following constraints:

$U^G - u \geq U^M - u + f\left(e^M-\Delta\theta\right)$

$U^M - u \geq U^B - u + f\left(e^B-\Delta\theta\right)$

remain satisfied.

We also have $U^M \geq U^B \geq 0$ and $U^G \geq U^M \geq 0$.

The solution $(\varepsilon^G,\varepsilon^M,\varepsilon^B,U^G-u,U^M-u,U^B-u)$ obtained from the optimal solution $(\varepsilon^G,\varepsilon^M,\varepsilon^B,U^G,U^M,U^B)$ is still feasible, while the value of the objective function is higher (with *u*) than the optimal value. This is a contradiction with the assumption that $(\varepsilon^G,\varepsilon^M,\varepsilon^B,U^G,U^M,U^B)$ represents the optimal solution.

Therefore, at the optimum it must be $U^B = 0$.

In the same way we can prove that $U^M = f\left(e^B - \Delta\theta\right)$ and $U^G = U^M + f\left(e^M - \Delta\theta\right) = f\left(e^B - \Delta\theta\right) + f\left(e^M - \Delta\theta\right)$.

Using the above result, we can now check that the optimal informational rents satisfy the downward local and global incentive constraints.

Indeed, the constraint (14) becomes:

$$f(e^M) \geq U^M = f\left(e^B - \Delta\theta\right)$$

or $e^M \leq e^B - \Delta\theta$ (and this is true from the implementability condition).

The constraint (13), using the optimal expressions for U^M and U^G can be written as:

$$f\left(e^B - \Delta\theta\right) \geq f\left(e^B - \Delta\theta\right) + f\left(e^M - \Delta\theta\right) + f\left(e^G\right)$$

or $e^G \leq e^M - \Delta\theta$ (and this is also true from the implementability condition).

The downward global incentive constraint is simply implied by the two local constraints. Adding them we get:

$$U^B \geq U^G - f\left(e^G\right) - f\left(e^M\right) \geq U^G - f\left(e^G\right) - f\left(e^G + \Delta\theta\right)$$

or $f\left(e^G + \Delta\theta\right) \geq f\left(e^M\right)$ or $e^G \leq e^M - \Delta\theta$ (and this is true from the implementability condition).

With this huge simplification on the set of incentive feasible contracts, the optimization problem is significantly reduced and becomes an unconstrained optimization problem. Hence, the problem to be solved is:

$$\underset{\varepsilon^G,\varepsilon^M,\varepsilon^B}{(\max)}\ F(\varepsilon^G, \varepsilon^M, \varepsilon^B) = \gamma^G\left[\pi^m(c^G + \varepsilon^G) + \varepsilon^G D^m\left(\varepsilon^G + c^G\right)\right] +$$

$$(\mathrm{P^r}) + \gamma^M\left[\pi^m\left(c^M + \varepsilon^M\right) + \varepsilon^M D^m\left(c^M + \varepsilon^M\right)\right] +$$

$$+ \gamma^B\left[\pi^m\left(c^B + \varepsilon^B\right) + \varepsilon^B D^m\left(c^B + \varepsilon^B\right)\right] -$$

$$- \gamma^G\left[f\left(e^B - \Delta\theta\right) + f\left(e^M - \Delta\theta\right)\right] - \gamma^M f\left(e^B - \Delta\theta\right)$$

The optimal contract satisfies the following first order conditions (the program being concave, these conditions are also sufficient conditions):

a) $\dfrac{\partial F(\cdot)}{\partial \varepsilon^G} = 0$ yields to:

$$\gamma^G\left[\frac{d\pi^m(c^G + \varepsilon^G)}{d\varepsilon^G} + D^m(c^G + \varepsilon^G) + \varepsilon^G D'^m(c^G + \varepsilon^G)\right] = 0$$

or

$$\varepsilon^G D'^m(c^G + \varepsilon^G) = 0$$

or

$\bar{\varepsilon}^G = 0$ (the second best solution is the same as the first best solution for this type of Agent).

b) $\dfrac{\partial F(\cdot)}{\partial \varepsilon^M} = 0$ yields to:

$$\gamma^M \varepsilon^M D'^m (c^M + \varepsilon^M) - \gamma^G \left[\frac{d\pi^m (c^G + \varepsilon^M)}{d\varepsilon^M} - \frac{d\pi^m (c^M + \varepsilon^M)}{d\varepsilon^M} \right] = 0 \text{ or:}$$

$$\gamma^M \varepsilon^M D'^m (c^M + \varepsilon^M) - \gamma^G f'\left(\varepsilon^M + c^G\right) = 0 .$$

Solving for $\bar{\varepsilon}^M$ it follows immediately that $\bar{\varepsilon}^M > 0$.

Using the function $f(e) = \pi^m(e) - \pi^m(e + \Delta\theta)$ in the above relation we get:

$$\gamma^M \varepsilon^M D'^m (c^M + \varepsilon^M) - \gamma^G \left[\frac{d\pi^m (c^G + \varepsilon^M)}{d\varepsilon^M} - \frac{d\pi^m (c^M + \varepsilon^M)}{d\varepsilon^M} \right] = 0$$

or:

$$\gamma^M \varepsilon^M D'^m (c^M + \varepsilon^M) + \gamma^G \left[D^m (\varepsilon^M + c^G) - D^m (\varepsilon^M + c^M) \right] = 0 \qquad (16)$$

c) From $\dfrac{\partial F(\cdot)}{\partial \varepsilon^B} = 0$

it follows that:

$$\gamma^B \left[\frac{d\pi^m (c^B + \varepsilon^B)}{d\varepsilon^B} + D^m (c^B + \varepsilon^B) + \varepsilon^B D'^m (c^B + \varepsilon^B) \right] -$$

$$\gamma^G f'\left(e^B - \Delta\theta\right) - \gamma^M f'\left(e^B - \Delta\theta\right) = 0$$

Using again the function $f(\cdot)$, the above equation becomes:

$$\gamma^B \varepsilon^B D'^m (c^B + \varepsilon^B) - (\gamma^G + \gamma^M) f'\left(e^B - \Delta\theta\right) = 0$$

or

$$\gamma^B \varepsilon^B D'^m (c^B + \varepsilon^B) - (1 - \gamma^B) \left[\frac{d\pi^m (c^M + \varepsilon^B)}{d\varepsilon^B} - \frac{d\pi^m (c^B + \varepsilon^B)}{d\varepsilon^B} \right] = 0$$

or

$$\gamma^B \varepsilon^B D'^m (c^B + \varepsilon^B) + (1 - \gamma^B) \left[D^m (\varepsilon^B + c^M) - D^m (\varepsilon^B + c^B) \right] = 0 \qquad (17)$$

If we denote by $\bar{\varepsilon}^B$ the solution of the equation given in (17), then it must satisfy $\bar{\varepsilon}^B > 0$.

d) The remaining variables $\overline{F}^G, \overline{F}^M$ and $\overline{F}^B$ can be derived using the definitions of the informational rents (1), (2), (3), the results from *Proposition 2* and the result $\bar{\varepsilon}^G = 0$ and the relations (16) and (17).

Therefore, we have:

$$\overline{F}^G = \pi^m(c^G + \overline{\varepsilon}^G) - \pi^m(c^0) - \overline{U}^G =$$
$$= \pi^m(c^G) - \pi^m(c^0) - \pi^m(c^M + \overline{\varepsilon}^B) + \pi^m(c^B + \overline{\varepsilon}^B) - \tag{18}$$
$$- \pi^m\left(c^G + \overline{\varepsilon}^M\right) + \pi^m\left(c^M + \overline{\varepsilon}^M\right)$$

and:

$$\overline{F}^M = \pi^m(c^M + \overline{\varepsilon}^M) - \pi^m(c^0) - \overline{U}^M =$$
$$= \pi^m(c^M + \overline{\varepsilon}^M) - \pi^m(c^0) - \pi^m(c^M + \overline{\varepsilon}^B) + \pi^m(c^B + \overline{\varepsilon}^B) \tag{19}$$

and:

$$\overline{F}^B = \pi^m(c^B + \overline{\varepsilon}^B) - \pi^m(c^0) \tag{20}$$

We can now summarize the features of the optimal contracts in asymmetric information:

Theorem 3. In the situation of asymmetric information, the optimal licensing contract (the second best solution) entails:

A. *Optimal variable fees*:

- The contract designed for the type with the lowest average cost (the innovation with type G) is completely based on fixed fees. Therefore, at the optimum we have:
  $\overline{\varepsilon}^G = 0 = \tilde{\varepsilon}^G$.
- The contracts designed for the Agents with higher average costs (the innovation has the type *M* or *G*) entail strictly positive variables fees, $\overline{\varepsilon}^M > 0, \overline{\varepsilon}^B > 0$, derived from (16) and (17).

B. *Optimal informational rents*:

- The Agent with type B gets no informational rent such that $\overline{U}^B = 0$.
- The Agents with type *M* and *G* get strictly positive informational rents, due to the informational advantage. These informational rents have the following forms:

$$\overline{U}^M = f\left(\overline{\varepsilon}^B + c^B - \Delta\theta\right)$$

and:

$$\overline{U}^G = f(\overline{\varepsilon}^B + c^B - \Delta\theta) + f(\overline{\varepsilon}^M + c^M - \Delta\theta)$$

C. *Optimal fixed fees*:

- The contract designed for the type G is completely based on a fixed fee, given by (18):

$$\overline{F}^G = \pi^m(c^G + \overline{\varepsilon}^G) - \pi^m(c^0) - \overline{U}^G$$

- The contracts designed for the types M and B entail the following optimal fixed fees, given by (19):

$$\overline{F}^M = \pi^m(c^M + \overline{\varepsilon}^M) - \pi^m(c^0) - \overline{U}^M$$

and by (20), respectively:

$$\overline{F}^B = \pi^m(c^B + \overline{\varepsilon}^B) - \pi^m(c^0) .$$

4. An example

Suppose that the demand function for the good produced by the potential buyer (of the license) is:

$D(P) = a - bP$, with $a, b \in (0, \infty)$

(the parameters a and b can be easily estimated).

Then, the price maximizing the firm's profit satisfies:

$$P^m(x) \in \arg\max_P (P - x)D(P)$$

where x represents the average production cost.

It is easy to find the optimal value for the price; it is given by:

$$P^m(x) = \frac{a + bx}{2b}$$

With the above expression for the price, the demand function becomes:

$D^m(x) = \dfrac{a - bx}{2}$, with $D'^m(x) = -\dfrac{b}{2}$

And hence, the profit function is now:

$$\pi^m(x) = \frac{(a - bx)^2}{4b}$$

Our goal is to derive the optimal menu of contracts in both situations, symmetric and asymmetric situations.

Using the results from the previous sections, the optimal contracts in symmetric information have the following form:

- for type G: $(\tilde{F}^G, \tilde{\varepsilon}^G = 0)$, where $\tilde{F}^G = \dfrac{(c^0 - c^G)[2a - b(c^0 + c^G)]}{4}$;
- for type M: $(\tilde{F}^M, \tilde{\varepsilon}^M = 0)$, where $\tilde{F}^M = \dfrac{(c^0 - c^M)[2a - b(c^0 + c^M)]}{4}$;
- for type B: $(\tilde{F}^B, \tilde{\varepsilon}^B = 0)$, where $\tilde{F}^B = \dfrac{(c^0 - c^B)[2a - b(c^0 + c^B)]}{4}$.

We consider now the case of asymmetric information. We derive the corresponding optimal menu of contracts using the results from *Theorem 3*.

1) Optimal variable fees

From the first order conditions we have:

$$\bar{\varepsilon}^G = 0 \qquad (1')$$

Then, the equation (16) becomes:

$$-\frac{b}{2}\gamma^M \varepsilon^M + \gamma^G \left[\frac{a - b(\varepsilon^M + c^G)}{2} - \frac{a - b(\varepsilon^M + c^M)}{2} \right] = 0$$

and this yields to:

$$\bar{\varepsilon}^M = \frac{\gamma^G}{\gamma^M}\left(c^M - c^G\right) = \frac{\gamma^G}{\gamma^M}\Delta\theta \qquad (2')$$

Using (17), we get:

$$-\frac{b}{2}\gamma^B \varepsilon^B + \left(1 - \gamma^B\right)\left[\frac{a - b(\varepsilon^B + c^M)}{2} - \frac{a - b(\varepsilon^B + c^B)}{2} \right] = 0$$

or:

$$\bar{\varepsilon}^B = \frac{1-\gamma^B}{\gamma^B}\left(c^B - c^M\right) = \left(\frac{1-\gamma^B}{\gamma^B}\right)\Delta\theta \qquad (3')$$

2) We derive now the optimal *informational rents*.

In order to go further we need to make an additional assumption. We suppose that the average production costs (assigned to three possible types of innovation) are such that

$\Delta\theta = c^B - c^M = c^M - c^G = 1$ and $c^0 - c^B = 1$

With this new assumption, the optimal variable fees $\left(\bar{\varepsilon}^G, \bar{\varepsilon}^M, \bar{\varepsilon}^B\right)$ become: $\left(0, \frac{\gamma^G}{\gamma^M}, \frac{1-\gamma^B}{\gamma^B}\right)$.

The function $f(e)$ has the form:

$$f(e) = \pi^m(e) - \pi^m(e+1) = \frac{2a - b - 2be}{4}$$

From *Proposition 2*, the optimal informational rents are:

$\bar{U}^B = 0$, $\bar{U}^M = f\left(\bar{e}^B - \Delta\theta\right)$ and $\bar{U}^G = f(\bar{e}^B - \Delta\theta) + f(\bar{e}^M - \Delta\theta)$

where:

$$\bar{e}^B = \bar{\varepsilon}^B + c^B = \frac{1}{\gamma^B} + c^0 - 2$$

and:

$$\overline{e}^{M} = \overline{\varepsilon}^{M} + c^{M} = \frac{\gamma^{G}}{\gamma^{M}} + c^{0} - 2 .$$

Therefore, the final form for the optimal rents are written as:

$$\overline{U}^{B} = 0 \qquad (4')$$

$$\overline{U}^{M} = f\left(\frac{1}{\gamma^{B}} + c^{0} - 3\right) = \frac{a}{2} + \frac{b}{4}\left(5 - 2c^{0} - \frac{2}{\gamma^{B}}\right) \qquad (5')$$

and

$$\overline{U}^{G} = \frac{a}{2} + \frac{b}{2}\left(5 - 2c^{0} - \frac{1}{\gamma^{B}} - \frac{\gamma^{G}}{\gamma^{M}}\right) \qquad (6')$$

3) The second best *transfers (fixed fees)* $\overline{F}^{G}, \overline{F}^{M}$ and $\overline{F}^{B}$ are given by the relations (18), (19) and (20). Therefore, we have:

$$\overline{F}^{B} = \frac{\left[a - b\left(c^{B} + \overline{\varepsilon}^{B}\right)\right]^{2}}{4b} - \frac{\left(a - bc^{0}\right)^{2}}{4b}$$

or

$$\overline{F}^{B} = a\left(1 - \frac{1}{2\gamma^{B}}\right) + \frac{b}{4}\left(\frac{1}{\gamma^{B}} - 2\right)\left(2c^{0} + \frac{1}{\gamma^{B}} - 2\right) \qquad (7')$$

From (19) we have:

$$\overline{F}^{M} = \pi^{m}\left(c^{M} + \overline{\varepsilon}^{M}\right) - \pi^{m}(c^{0}) - \overline{U}^{M}$$

which can be rewritten as:

$$\overline{F}^{M} = \frac{\left[a - b\left(c^{M} + \overline{\varepsilon}^{M}\right)\right]^{2}}{4b} - \frac{\left(a - bc^{0}\right)^{2}}{4b} + $$

$$+ \frac{\left[a - b\left(\overline{\varepsilon}^{B} + c^{B}\right)\right]^{2}}{4b} - \frac{\left[a - b\left(\overline{\varepsilon}^{B} + c^{M}\right)\right]^{2}}{4b}$$ or:

$$\overline{F}^{M} = \frac{a}{2}\left(1 - \frac{\gamma^{G}}{\gamma^{M}}\right) + \frac{b}{4}\left[\frac{2}{\gamma^{B}} + 2c^{0} - 5 + \left(\frac{\gamma^{G}}{\gamma^{M}} - 2\right)\left(2c^{0} + \frac{\gamma^{G}}{\gamma^{M}} - 2\right)\right] \qquad (8')$$

From (20) we have:

$$\overline{F}^{G} = \pi^{m}\left(c^{G} + \overline{\varepsilon}^{G}\right) - \pi^{m}(c^{0}) - \overline{U}^{G}$$

which can be rewritten as:

$$\overline{F}^{G} = \frac{\left[a - bc^{G}\right]^{2}}{4b} - \frac{\left(a - bc^{0}\right)^{2}}{4b} + \frac{\left[a - b\left(\overline{\varepsilon}^{B} + c^{B}\right)\right]^{2}}{4b} - \frac{\left[a - b\left(\overline{\varepsilon}^{B} + c^{M}\right)\right]^{2}}{4b} +$$

$$+ \frac{\left[a - b\left(\overline{\varepsilon}^{M} + c^{M}\right)\right]^{2}}{4b} - \frac{\left[a - b\left(\overline{\varepsilon}^{M} + c^{G}\right)\right]^{2}}{4b}$$

or:

$$\overline{F}^{G} = \frac{a}{2} + \frac{b}{4}\left(\frac{2}{\gamma^{B}} + \frac{2\gamma^{G}}{\gamma^{M}} - 2c^{0} - 1\right) \qquad (9')$$

We can summarize the results in the next table:

Table 1

The results: optimal contracts in symmetric/asymmetric information

Innovation type	Optimal contracts in symmetric information	Optimal contracts in asymmetric information
Type G	$\tilde{\varepsilon}^{G} = 0$ $\tilde{F}^{G} = \frac{3a}{2} + \frac{3b}{4}\left(3 - 2c^{0}\right)$	$\overline{\varepsilon}^{G} = \tilde{\varepsilon}^{G} = 0$ $\overline{F}^{G} = \frac{a}{2} + \frac{b}{4}\left(\frac{2}{\gamma^{B}} + \frac{2\gamma^{G}}{\gamma^{M}} - 2c^{0} - 1\right)$
Type M	$\tilde{\varepsilon}^{M} = 0$ $\tilde{F}^{M} = a + b\left(1 - c^{0}\right)$	$\overline{\varepsilon}^{M} = \frac{\gamma^{G}}{\gamma^{M}}$ $\overline{F}^{M} = \frac{a}{2}\left(1 - \frac{\gamma^{G}}{\gamma^{M}}\right) +$ $+ \frac{b}{4}\left[\frac{2}{\gamma^{B}} + 2c^{0} - 5 + \left(\frac{\gamma^{G}}{\gamma^{M}} - 2\right)\left(2c^{0} + \frac{\gamma^{G}}{\gamma^{M}} - 2\right)\right]$
Type B	$\tilde{\varepsilon}^{B} = 0$ $\tilde{F}^{B} = \frac{a}{2} + \frac{b}{2}\left(1 - 2c^{0}\right)$	$\overline{\varepsilon}^{B} = \frac{1 - \gamma^{B}}{\gamma^{B}}$ $\overline{F}^{B} = a\left(1 - \frac{1}{2\gamma^{B}}\right) + \frac{b}{4}\left(\frac{1}{\gamma^{B}} - 2\right)\left(2c^{0} + \frac{1}{\gamma^{B}} - 2\right)$

Remark: The variables values found in this particular problem (the results of this application) are very sensitive to the assumptions made on the demand function form, the beliefs of the Principal with respect to the average production cost of the Agent (the probabilities) and the assumption regarding the spread of the adverse selection parameter values.

Conclusions

We analyzed in the paper the effects of asymmetric information between an owner of an innovation and the potential buyer (having a monopoly position) on the design of optimal licensing contracts. The main assumption of the model proposed here is that the innovation can have one of three possible types and these types influence the average production cost. If it is the buyer who has private information innovation's type, then the type with the lowest average cost receives a contractual offer entirely based on fixed fees and this type gets a positive informational rent. On the other hand, if the firm (monopoly) has a low evaluation about the innovation (the average costs are still high), then the contract designed by the Principal is based also on variable fees. The approach presented can be easily generalized for a finite number of Agent's types (finite number of possible types of innovation), fitting better to empirical studies.

Acknowledgements

This work was cofinanced from the European Social Fund through Sectoral Operational Programme Human Resources Development 2007-2013, project number POSDRU/1.5/59184 "Performance and excellence in postdoctoral research in Romanian economics science domain".

References

Anand, B.N., Khanna T., „The Structure of Licensing Contracts", *The Journal of Industrial Economics*, 48, 2000, pp.103-135

Antelo, M., „On Contract Duration of Royalty Licensing Contracts", *Spanish Economic Review*, 11, 2009, pp.277-299

Beggs, A.W., „The Licensing of Patents under Asymmetric Information", *International Journal of Industrial Organization*, 10, 2002,pp.171-194

Crama, P., Peyck, B., Degraeve, Z., „Milestone Payments or Royalties? Contract Design for R&D Licensing", *Operations Research*, 56, 2008, pp. 1539-1552

Erutku, C., Freire, A.P., Richelle, Y., „Licensing Innovations with Exclusive Contracts", *Review of Industrial Organization*, 31, 2007, pp.261-273

Gallini, N.T., Wright, B.D., „Technology Transfer under Asymmetric Information", *Rand Journal of Economics*, 21, 1990, pp. 147-160

Jensen, R., Thursby, M., „Proofs and Prototypes for Sale: the Licensing of University Inventions", *American Economic Review*, 91, 2001, pp. 240-259

Katz, M.L., Shapiro, C., „On the Licensing of Innovations", *Rand Journal of Economics*, 16, 1985, pp.504-520

Laffont, J.J., Martimort, D. (2002). *The Theory of Incentives. The Principal-Agent Model*, Princeton University Press

Macho-Stadler, I., Perez-Castrillo, D.J., „Contrats de License et Asymetrie d'information", *Annales d'Economie et de Statistique*, 24, 1991, pp. 189-208

Macho-Stadler, I., Martinez-Giralt, X., Perez-Castrillo, D.J., 1996, „The Role of Information in Licensing Contract Design", *Research Policy*, 25, pp. 43-57

Marinescu, D., Marin, D., Optimal Licensing Contracts with Adverse Selection and Informational Rents, *Theoretical and Applied Economics*, 6, 2011, pp. 27-46

Mukherjee, A., Broll, U., Mukherjee, S., „Unionized Labor Market and Licensing by a Monopolist", *Journal of Economics*, 93, 2008, pp. 59-79

Watanabe, N., Muto, S., „Licensing Agreements as Bargaining Outcomes: general results and two examples", *Advances in Mathematical Economics*, 8, 2006, pp. 433-447