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Merging to license: internal vs. external patentee*

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Abstract

In this paper, we endogenize the decision of a research laboratory that owns a patented process innovation on whether to remain independent as an external patentee or to merge with a manufacturing firm, becoming an internal to the industry patentee. We show that a merger is profitable only for the case of small innovations whereas only large innovations make it welfare improving. As a consequence, the antitrust authority should forbid all (profitable) mergers.

Keywords: Patent licensing, two-part tariff contracts, external vs. internal patentee.

JEL Classification: D43; D45; L41

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1. Introduction

Generation of innovations is mainly carried out by either specialized research laboratories or by the R&D departments of manufacturing firms. In the former case, they make profits by licensing their patents. In the latter, firms may also exploit their innovations themselves. The focus of this paper is to analyze the endogenous decision of a research laboratory on whether to remain independent or to merge with a manufacturing firm in the industry, as well as its implications for antitrust. In other words, we aim to compare in terms of profits and welfare a case in which the innovating firm is external to the industry (an independent laboratory) with another in which the innovating firm becomes an internal to the industry patentee. For example, in 1999 Celltech Chiroscience, a science-driven biotechnology firm merged with Medeva, a pharmaceutical firm, creating Celltech Group, the UK's fourth largest pharmaceutical firm. Peter Fellner, Celltech's chief executive argued that the merger was aimed principally at retaining a greater share of profits by pushing products through its own sales force rather than licensing them out (Financial Times).

Apart from being a rather common phenomenon, the comparison proposed is also interesting from the point of view of the patent licensing literature because, to the best of our knowledge, no paper had endogenized the decision on whether to be an external or an internal patentee. So far, this literature has mainly focused on deriving optimal licensing contracts when the patentee is either an external or an internal to the industry patentee. We aim to study whether it is more profitable to license the innovations as an independent laboratory or to have also the possibility to exploit them by directly participating in the market.

For the case of an external patentee, Kamien and Tauman (1984, 1986), Katz and Shapiro (1986), Kamien et al. (1992) show that licensing a non-drastic innovation by means of a royalty is less profitable than licensing it by means of a fixed fee or an auction. Much of this literature was reviewed in Kamien (1992).

Regarding the case of an internal patentee Wang (1998), Wang and Yang (1999), Kamien and Tauman (2002) show that a royalty is preferred to a fixed fee by the patentee.

In the context of perfect and complete information, however, only a few papers have investigated optimal two-part tariff contracts¹, namely, Kamien and Tauman (1984), who focus on the case of linear royalties based on output and perfect competition, Erutku and Richelle (2000), who analyze two-part tariff contracts including non-linear royalties based on either output or sales² (both papers focus on the case of an external to the industry patentee) and, finally, Faulí-Oller and Sandonís (2002) and Filippini (2002). Both papers analyze the collusive effect played by royalties in licensing contracts. In the former, the authors derive the optimal two-part tariff contract to license a cost reducing innovation in a differentiated Cournot and Bertrand duopoly setting for the case in which the patentee is internal to the industry. The latter complements ours by extending this results to a Stackelberg framework.

In this paper, with the aim to compare both an external and an internal patentee, we use the result on the optimal two-part tariff contract for the case of an internal patentee derived in Faulí-Oller and Sandonís (2002) and derive the optimal two-part tariff contract for the case of an external patentee licensing the innovation to a differentiated Cournot duopoly. This result, which is not central to this paper is, to our view, an important contribution to the patent licensing literature leading to interesting results. In particular, we obtain a similar result than in the case of an internal patentee, namely that, in order to control market competition, a royalty is *always* included in the optimal contract. This contrasts with the traditional view arguing that fixed fees are superior to royalties for the case of an external patentee.

The main result of the paper regarding the comparison between an internal and an external patentee is based on the balance of two forces. On the one hand, being an internal patentee allows the laboratory to better internalize market profits whereas an external paten-

¹Although the patent licensing literature has focused mainly on the comparison between royalties and fixed fees, existing empirical evidence reveals that many licensing contracts observed in practice include two parts, a fixed fee plus a linear royalty. In particular, Rostocker (1984), for example, finds that both instruments together are used 46% of the time, royalty alone 39% and fixed fee alone 13%. Calvert (1964), Taylor and Silberston (1973) and Macho-Stadler et al. (1996) report similar percentages.

²Erutku and Richelle (2000), for the case of an external to the industry patentee, show that by using two-part tariff contracts that include non-linear royalties based on sales, an external patentee can *always* design a sophisticated contract that allows her to get the monopoly profits, leading licensees' profits to zero. They show that, in that framework, even licensing small innovations may lead to reduce social welfare.

tee has to care also about reducing the licensees's profits in case they refuse the contracts, namely, their external options. On the other hand, whereas an external patentee may use two instruments (one contract for each firm) to affect the market outcome, an internal patentee loses the commitment capacity to restrict its own output because he can only use one instrument (the contract offered to the remaining independent firm).

We show that which of the two effects dominates depends on the size of the innovation. For large innovations, the profits that any firm can obtain by refusing the contract offered by the external patentee are low, which allows the patentee to care mainly about market profits, as an internal patentee. As he can do it making use of one more instrument, being an external patentee must be more profitable.

On the contrary, for small innovations, the external option of the firms is large and thus, becoming an internal patentee turns out to be preferred, as the possibility to maximize market profits outweighs the loss of one instrument the internal laboratory bears.

The evolution of social welfare follows opposite direction as profits. For large innovations an external patentee takes advantage of the use of the two instruments, which increases its profits and tends to reduce social welfare. On the contrary, for small innovations, an internal patentee is able to better control market competition, which goes in the direction to harm welfare.

As the option of becoming an internal to the industry patentee implies a merger between the laboratory and one of the firms in the industry, the antitrust authority has the possibility to block the process whenever the merger hurts welfare. We show in the paper that any profitable merger reduces social welfare. Thus, if we consider that the antitrust authorities can approve or reject only mergers that are proposed by the merging partners (i.e., profitable mergers), we can give a clear prescription. In our context, no merger should be allowed.

The rest of the paper is organized as follows. In the next section we derive the optimal licensing contracts for the case where the patentee is an independent laboratory and also an internal to the industry patentee. Section 3 deals with the comparison of profits and welfare between the two cases. We conclude in Section 4.

2. Optimal two part tariff licensing contracts

2.1. The case of an external laboratory

We consider two firms, denoted by $i = 1, 2$, each producing a differentiated good (goods 1 and 2 respectively). They face inverse demand functions given by:

$$p_i = 1 - x_i - \gamma x_j, i, j = 1, 2, i \neq j$$

where $\gamma \in [0, 1]$ represents the degree of product differentiation. These demands are derived from the maximization problem of a representative consumer (see Singh and Vives (1984)), endowed with a utility function separable in money (denoted by m) given by:

$$u(x_1, x_2) = x_1 + x_2 - \frac{x_1^2}{2} - \frac{x_2^2}{2} - \gamma x_1 x_2 + m$$

The two firms have constant unit production costs of c . There exists an independent laboratory that have a patented process innovation that allows to produce the two goods at a lower marginal cost, that we set, without loss of generality, to be zero. Thus, c can also be interpreted as the size of the innovation.

Let us define the social welfare function as:

$$W(x_1, x_2) = u(x_1, x_2) - c_1 x_1 - c_2 x_2,$$

where $c_i = 0$, $i = 1, 2$, if the technology is licensed to firm i and $c_i = c$ otherwise.

The timing of the game is as follows: In the first stage, the laboratory offers a contract to each firm on a take-it-or-leave-it basis. In the second stage, the potential licensees decide whether to accept or reject the contract. Finally, both firms compete in quantities. We look for the subgame perfect Nash equilibrium of the proposed game, solving it by backward induction. A contract offered to firm i is defined as a pair (f_i, r_i) , where f_i represents a fixed fee and r_i a per-unit of output royalty. We do not allow for negative fees because,

otherwise, as argued by Katz and Shapiro (1985), contracts would include the possibility for the patent holder to “bribe(s) firms to exit the industry...and would likely be held to be illegal by antitrust authorities.”

In the third stage, the equilibrium quantities and profits if both firms have accepted the contract are given by:

$$X_i(r_i, r_j) = \max\left\{\min\left\{\frac{1 - r_i}{2}, \frac{(2 - \gamma) - 2r_i + \gamma r_j}{4 - \gamma^2}\right\}, 0\right\},$$

$$\pi_i(r_i, r_j) = X_i^2, i, j = 1, 2, i \neq j.$$

In order to obtain the equilibrium if firm i has not accepted the contract, one has to replace r_i by c in the expressions above.

Let us now derive the optimal two-part tariff contract (s) to license the innovation. There are two possibilities. On the one hand, the laboratory can offer a contract to each firm. On the other hand, it can decide to offer a contract to only one firm. In the latter case there are again two possibilities. Either the firm that does not receive an offer is active in the market once the other firm has accepted the licensing contract or not. It is direct to see that it is not optimal to license to only one firm whenever the other firm is going to be active in the market (either because c is not very large and/or because the royalty imposed to the licensee is not very small). That strategy would be dominated by offering the second firm a contract with a royalty equal to c and no fixed fee. This contract would not change the royalty revenues from the first firm but would allow the laboratory to get additional revenues from the second firm. So the other possibility is that the laboratory offers a contract to one firm so that the other firm is not going to be active in the market stage. But this situation would be similar to offering the second firm a licensing contract including the lowest royalty such that, given c and the contract offered to the first firm, this firm would produce zero output in equilibrium. But this situation is a possibility taken into account in the resolution of the maximization problem we solve below for the case in which the two potential licensees are offered a contract.

In order for firm i to accept the contract it must satisfy $f_i \leq \pi_i(r_i, r_j) - \pi_i(c, r_j)$. Observe

that in this case the only equilibrium in the second stage is both firms accepting the licensing contract, because accepting is a strictly dominant strategy. If firm j accepts, firm i also prefers to accept³, because $\pi_i(c, r_j) \leq \pi_i(r_i, r_j) - f_i$. But even if firm j does not accept, firm i prefers to accept, because:

$$\pi_i(r_i, c) - f_i \geq \pi_i(r_i, c) - \pi_i(r_i, r_j) + \pi_i(c, r_j) \geq \pi_i(c, c)$$

The last inequality comes from the fact that $\frac{\partial^2 \pi_i}{\partial c_i \partial c_j} < 0$.

The optimal contract for the patentee then solves:

$$\begin{aligned} & \underset{f_1, f_2, r_1, r_2}{Max} \{r_1 X_1(r_1, r_2) + r_2 X_2(r_2, r_1) + f_1 + f_2\} \\ & \text{s.t. } f_1 \leq \pi_1(r_1, r_2) - \pi_1(c, r_2) \\ & \quad f_2 \leq \pi_2(r_2, r_1) - \pi_2(c, r_1) \\ & \quad f_1 \geq 0, f_2 \geq 0. \end{aligned}$$

As the first two restrictions should be binding in equilibrium, the previous maximization program can be rewritten in the following way:

$$\begin{aligned} & \underset{r_1, r_2}{Max} \{r_1 X_1(r_1, r_2) + r_2 X_2(r_2, r_1) + \pi_1(r_1, r_2) + \pi_2(r_2, r_1) \\ & \quad - \pi_1(c, r_2) - \pi_2(c, r_1)\} \\ & \text{s.t. } r_1 \leq c, r_2 \leq c. \end{aligned}$$

Direct resolution of the maximization program leads to the following result:

Proposition 2.1. *The optimal contract is given by:*

$$\begin{aligned} r_1^* = r_2^* = r^* &= \frac{\gamma(4c + (-2 + \gamma)\gamma)}{2(4 - 2\gamma^2 + \gamma^3)} \\ f_1^* = f_2^* = f^* &= \pi_1(r^*, r^*) - \pi_1(c, r^*). \end{aligned}$$

³In order to avoid the open set problem, firms are assumed to accept licensing contracts when they are indifferent between accepting and not accepting.

The maximization program involves the balance of two opposite effects: by increasing the royalties market profits increase but, at the same time, the profits to be obtained by the potential licensees by refusing the contract $(\pi_i(c, r_j), i = 1, 2)$ also increase. The balance of the two effects leads to an optimal royalty that falls short of the one that would maximize market profits $(r^* = \frac{\gamma}{2(1+\gamma)})$, except when the c is so large $(c \geq \frac{4+2\gamma-\gamma^2}{4(1+\gamma)} = c^M)$ that each potential licensee gets zero profits when refusing the contract. In this case, the maximization problem implies maximizing market profits and then the laboratory can obtain the full monopoly profits. Observe that the optimal royalty is strictly lower than c , which implies that the constraint of non-negative fixed fees is never binding. On the other hand, for the case of small innovations, the incentive to reduce the outside option of the licensees could lead the laboratory to charge a negative royalty which would be compensated with a higher fixed fee.

Finally, we can compute the equilibrium profits obtained by the laboratory and the licensees which will be useful to study merger profitability in the next section. They are given respectively by⁴:

$$\begin{aligned}\Pi_l &= r^*(X_1(r^*, r^*) + X_2(r^*, r^*)) + 2f^*, \\ \Pi_1 &= \Pi_2 = \pi_1(r^*, r^*) - f^*.\end{aligned}$$

2.2. The case of an internal to the industry patentee

Let us now analyze the case where the independent laboratory and one of the firms in the industry (say firm 1) have merged. This implies that the merged firm obtains revenues from licensing the innovation $(r_2 X_2(r_2, 0) + f_2)$ and also from selling good 1 directly to consumers making use of the patented technology $(\pi_1(0, r_2))$. That is to say, now we have to analyze the case of an internal to the industry patentee. In this case, the timing of the game is as follows: first the patentee offers a licensing contract to firm 2, then firm 2 decides whether

⁴Actual expressions have been relegated to Appendix A.

to accept or reject it and, finally, market competition takes place.

This model has been previously analyzed in Faulí-Oller and Sandonís (2002).

In the first stage, the merged firm looks for the contract (f_2, r_2) that solves:

$$\begin{aligned} & \max_{f_2, r_2} \{ \pi_1(0, r_2) + r_2 X_2(r_2, 0) + f_2 \} \\ & s.t. \quad f_2 \leq \pi_2(r_2, 0) - \pi_2(c, 0) \end{aligned}$$

This program can be written in a simplified way. As the first constraint is always binding, it can be substituted in the objective function. The maximization problem thus becomes:

$$\begin{aligned} & \max_{r_2} \{ \pi_1(0, r_2) + r_2 X_2(r_2, 0) + \pi_2(r_2, 0) - \pi_2(c, 0) \} \\ & s.t. \quad r_2 \leq c. \end{aligned}$$

Before solving the program and in order to better understand the main results in this work it is useful to compare the maximization problems of both the external and the internal patentee. In the latter case, the royalty is set to maximize market profits because the outside option of the licensee $(\pi_2(c, 0))$ does not depend on the royalty. In the former case, however, the royalties affect both market profits and the outside option of firms. The fact that an internal patentee maximizes market profits tends to give the laboratory an advantage over the alternative of being an external patentee. We have to take into account, however, that the alignment with market profits maximization is achieved at the cost of losing one of the two instruments that were available to the laboratory when being an external patentee (an internal patentee can only choose one licensing contract whereas it can choose two contracts when being an external patentee). This reduces the flexibility of the internal patentee to affect the market outcome. Thus, the result on profitability of the merger between the laboratory and one of the firms depends on the balance of the two previous effects.

The resolution to the above program results directly in the following contract:

$$\begin{aligned} r_2^* &= \min \left\{ c, \frac{\gamma(2-\gamma)^2}{2(4-3\gamma^2)} \right\}, \\ f_2^* &= \pi_2(r_2^*, 0) - \pi_2(c, 0). \end{aligned}$$

Observe that the optimal contract always includes a positive royalty⁵. In this way, the patentee softens ex-post competition by raising the licensee's marginal cost of production. However, it never sets such a high royalty as to expel the licensee out of the market. The reason is that whenever the goods are not perfect substitutes, licensing the innovation allows the patentee to keep open the licensee's profitable market, and the royalty revenues obtained more than compensate him for the increase in market competition. This is true even for the case of a drastic innovation, namely, for values of c such that $X_2(c, 0) = 0$, which occurs whenever $c \geq c^N = (2 - \gamma)/2$. In other words, the merged firm prefers a duopoly to a monopoly in market one (see Proposition 4.2 in Faulí-Oller and Sandonís (2002)).

Finally, we can compute the equilibrium profits obtained by the merged firm. They are given by (see Appendix A):

$$\Pi_{l1} = \pi_1(0, r_2^*) + r_2^* X_2(r_2^*, 0) + \pi_2(r_2^*, 0) - \pi_2(c, 0).$$

3. Merger profitability and welfare

In this section we proceed to compare the two scenarios analyzed in the previous sections in terms of profits and social welfare, with the aim to evaluate first, the private incentives of the laboratory and one of the firms to merge in order to become an internal to the industry patentee and, second, the effect of such behavior on social welfare in order to be able to derive the optimal competition policy.

Regarding profitability we have to sign the difference between the profits of the merged firm and the sum of the profits of the external laboratory plus firm 1's profits, namely, the sign of $\Pi_{l1} - (\Pi_1 + \Pi_l)$. We obtain the following result:

Proposition 3.1. *A threshold value for the size of the innovation c_1 always exists such that below that value a merger between the laboratory and firm 1 is profitable.*

⁵In fact, one exception does exist: when $\gamma = 0$, $r_2^* = 0$. In this particular case, the patentee faces the same problem as an external laboratory licensing the innovation to a monopoly. In that case, we know that the laboratory prefers a fixed fee rather than a royalty (see Kamien and Tauman, 1986).

Proof. See Appendix B.

In order to grasp the main intuition of the proposition it is useful to discuss what happens when the innovation is so large that the current technology of firms cannot be used profitably by any firm when the new technology is licensed (namely, when $c > c^M$). In this extreme case, the external option of the licensees when the laboratory is external to the industry becomes zero, which means that the maximization program of the laboratory implies maximizing market profits by choosing two instruments (one contract for each firm). This allows the laboratory to implement the monopoly outcome and get the monopoly profits. As an internal patentee is not able to implement monopoly given that he can only use one instrument (a contract for firm 2), a merger between the laboratory and firm 1 cannot be profitable.

For smaller innovations the comparison is not clear because a trade-off arises. Now, the external patentee also cares about the profits that firms can obtain when rejecting the contracts, namely, their external options. The size of the external options is decreasing in the size of the innovation. Thus, when the innovation is small enough the objective of the external patentee is so distorted from profit maximization that, in spite of its lower flexibility, being an internal patentee becomes profitable.

Observe that we can extend the result in the above proposition to the case of homogeneous goods just by setting $\gamma = 1$. In that case, we get $c_1 = c^M$. This implies that vertical integration cannot be unprofitable because for $c > c^M$ we know that in both the integrated and disintegrated cases the monopoly outcome arises. Therefore, under homogeneous goods becoming an internal to the industry patentee must be always (weakly) profitable.

So far we have analyzed the private incentives of firms to merge. Given that mergers have to be approved by the competition authorities it is very useful to know their effect on social welfare. This is done in the next proposition.

Proposition 3.2. *Whenever the goods are not homogeneous, large enough innovations ($c > c^+$) make a merger between the laboratory and firm 1 welfare improving.*

Proof. See appendix B.

The good news for welfare of a merger between the laboratory and firm 1 is that the merged firm loses the commitment capacity to restrict its output as he cannot credibly increase its *own* marginal cost (zero), compared with the case of the external patentee where the laboratory charges a royalty (r^*) to each firm. The size of this positive effect on welfare ($r^* - 0$) is increasing in the size of the innovation. Large innovations allow the external laboratory to set higher royalties, distorting a lot outputs and welfare. When the innovation is small, however, the royalties have to be smaller and thus the positive effect on welfare produced by the merger is reduced.

The bad news for welfare of the merger is that the internal patentee completely internalizes market profits which induces him to reduce market competition by charging a higher royalty to the rival firm (r_2^*) compared to the royalty charged when he is an external patentee (r^*). This negative effect ($r_2^* - r^*$) is decreasing in the size of the innovation⁶. As a result, as the above proposition shows, for large enough innovations the merger between the laboratory and firm 1 becomes welfare improving.

We can again extend the result in the above proposition to the case of homogeneous goods just by setting $\gamma = 1$. In that case, we get $c^+ = c^M$. This implies that vertical integration cannot be welfare improving because for $c > c^M$ we know that in both the integrated and disintegrated cases the monopoly outcome arises. Therefore, under homogeneous goods becoming an internal to the industry patentee must be always bad for welfare.

If we consider that the antitrust authorities can approve or reject only mergers that are proposed by the merging partners (i.e., profitable mergers), in order to derive the optimal competition policy we have to combine the above proposition on welfare with the previous result on profitability.⁷

It is direct to see that $c^+ > c_1$ (in other words, profitable mergers are never welfare improving). Then, a very simple rule has to be followed by the antitrust authority: to forbid any merger between the external laboratory and one of the firms inside the industry.

⁶Notice that this is not the case when $r_2^* = c$ (the restricted case) but, in this case, the merger is always welfare reducing.

⁷It is possible that some unprofitable mergers increase welfare. However, compulsory action or subsidies to carry them through would go against the normal practices of antitrust policy.

4. Conclusions

In this paper we endogenize the decision of an independent research laboratory on whether to remain external to the industry or to merge with one of the firms in the industry in order to become an internal patentee. A basic trade-off arises. On the one hand, when being an external patentee the laboratory aims to maximize market profits minus the external option of firms, whereas becoming an internal patentee allows the laboratory to focus on maximizing market profits. On the other hand, being an external patentee gives the laboratory more flexibility to affect the market outcome as he can use two instruments (one contract for each firm) instead of only one instrument that can be used whenever he becomes an internal patentee. We show that the optimal decision on whether to be external or internal to the industry (profitability) and its effect on social welfare depend on the size of the innovation. In particular, when the innovation is large the external option of firms is small and, therefore, the objectives of both the external and the internal patentee are very similar. Thus, being an external patentee is more profitable because it gives the laboratory more flexibility to control the market outcome. When the innovation is small, the external option of firms is large and, therefore, becoming an internal patentee allows the laboratory to better internalize market profits and becomes profitable.

Regarding social welfare, a merger between the laboratory and one of the firms in the industry has two opposite effects. On the one hand, it is positive because the merged firm loses the commitment capacity to restrict its output compared with the case of the external patentee where the laboratory charges a royalty to each firm. The size of this positive effect on welfare depends on the size of the innovation. Large innovations allow the external laboratory to set higher royalties, distorting a lot outputs and welfare. When the innovation is small, however, the royalties have to be smaller and thus the positive effect on welfare produced by the merger is reduced.

On the other hand, the merged firm completely internalizes market profits which induces him to charge a higher royalty to the rival firm. This negative effect is decreasing in the size of the innovation. As we have shown in the paper, the positive effect of the merger

dominates for large enough innovations.

We use the results to design the optimal competition policy. Although we find some welfare improving mergers, they happen to be unprofitable for the firms and, therefore, they will never be presented for approval to the competition authorities. As subsidies or compulsory action to promote mergers would go against the normal practices of antitrust policy, the competition authorities should only care about the welfare effects of mergers that are profitable. To this respect we get a very clear result, namely, that all profitable mergers reduce welfare. Thus, the prescription should be to forbid all mergers.

5. Appendix

5.1. Appendix A

In the disintegrated case, the equilibrium profits of the laboratory and firms are given respectively by:

If $c < c^M$,

$$\begin{aligned}\Pi_l &= \frac{\gamma^4 - 16c^2(1 + \gamma) + 8c(4 + 2\gamma - \gamma^2)}{2(2 + \gamma)^2(4 - 2\gamma^2 + \gamma^3)}, \\ \Pi_1 &= \Pi_2 = \frac{(2 - \gamma)^2(4c(1 + \gamma) - 4 - 2\gamma + \gamma^2)^2}{4(2 + \gamma)^2(4 - 2\gamma^2 + \gamma^3)^2}.\end{aligned}$$

If $c \geq c^M$,

$$\begin{aligned}\Pi_l &= \frac{1}{2(1 + \gamma)}, \\ \Pi_1 &= \Pi_2 = 0,\end{aligned}$$

where $c^M = \frac{4 + 2\gamma - \gamma^2}{4(1 + \gamma)}$.

When the laboratory and firm 1 merge, their equilibrium profits are given by:

If $c \leq c_r$, then

$$\Pi_{1l} = \frac{(2 - \gamma)^2 + c^2(-8 + 3\gamma^2) + c(8 - 4\gamma^2 + \gamma^3)}{(4 - \gamma^2)^2}$$

If $c_r < c \leq c^N$, then

$$\Pi_{1l} = \frac{16c^2(-4 + 3\gamma^2) + 16c(8 - 4\gamma - 6\gamma^2 + 3\gamma^3) + (2 - \gamma)^2(16 - 8\gamma^2 - 4\gamma^3 + \gamma^4)}{4(4 - \gamma^2)^2(4 - 3\gamma^2)}.$$

Finally, if $c > c^N$, we have

$$\Pi_{ll} = \frac{8 - 8\gamma + \gamma^2}{4(4 - 3\gamma^2)}.$$

where $c_r = \frac{\gamma(2 - \gamma)^2}{2(4 - 3\gamma^2)}$ and represents the value of c that equals the optimal unrestricted royalty (r_2^*) and $c^N = \frac{2 - \gamma}{2}$.

5.2. Appendix B

Proof of Proposition 3.1

For $c \geq c^M$, the external option of the licensees when the laboratory is external to the industry becomes zero, which implies that the laboratory maximizes market profits by choosing two instruments (one contract for each firm). This allows the laboratory to implement the monopoly outcome and get the monopoly profits. As the internal patentee is not able to implement monopoly given that he can only use one instrument (a contract for firm 2), a merger between the laboratory and firm 1 cannot be profitable.

For $c^N \leq c < c^M$, the difference⁸ $\Pi_{l1} - (\Pi_1 + \Pi_l)$ is a concave function of c with two roots c^+ and c^- . We have that $c^+ > c^M$ and $c^N \leq c^- < c^M$ whenever $\gamma \geq 0.94$ and $c^- < c^N$ whenever $\gamma < 0.94$. Therefore, a merger between the laboratory and firm 1 is profitable in this region only when $\gamma \geq 0.94$ and $c < c^-$, where

$$c^- = \frac{1}{4(-16 - 16\gamma + 16\gamma^2 + 12\gamma^3 - 7\gamma^4 + 3\gamma^6)} \left(\begin{array}{l} -64 - 32\gamma + 80\gamma^2 + 16\gamma^3 - 36\gamma^4 + 10\gamma^5 + \\ + 9\gamma^6 - 3\gamma^7 + \gamma(8 + 4\gamma - 4\gamma - 4\gamma^2 + \gamma^4) \\ \sqrt{16 - 16\gamma - 16\gamma^2 + 20\gamma^3 - \gamma^4 - 6\gamma^5 + 3\gamma^6} \end{array} \right).$$

For $c_r \leq c < c^N$, the difference $\Pi_{l1} - (\Pi_1 + \Pi_l)$ is a convex function of c with two roots \tilde{c} and \hat{c} . We have that $\tilde{c} < c_r$ and $c_r < \hat{c} \leq c^N$ whenever $\gamma \leq 0.94$. For $\gamma > 0.94$, we have

⁸In this region the difference $\Pi_{l1} - (\Pi_1 + \Pi_l)$ is characterized by the fact that the outside option of firm 2 in the integrated case ($\pi_2(c, 0)$) becomes zero, that is, the threshold value c^N characterizes which is usually called in the literature *drastic innovation*.

that $\hat{c} > c^N$. Therefore, a vertical merger is profitable in this region whenever $\gamma \leq 0.94$ and $c \leq \hat{c}$, or when $\gamma > 0.94$, where

$$\hat{c} = \frac{2 - \gamma}{4\gamma^2(4 - 3\gamma^2)} \left[\frac{32 - 16\gamma - 40\gamma^2 + 24\gamma^3 + 8\gamma^4 - 9\gamma^5 + 3\gamma^6 +}{\sqrt{16 - 20\gamma^2 + 6\gamma^4}(8 - 4\gamma - 4\gamma^2 + 4\gamma^3 - \gamma^4)} \right].$$

Finally, for $0 \leq c < c_r$, the difference $\Pi_{l1} - (\Pi_1 + \Pi_l)$ is a convex function of c with two roots c_1 and c_2 . We have that $c_1 < 0$ and $c_2 > c_r$. Therefore, a merger between the laboratory and firm 1 is always profitable.

Summing up, the threshold value c_1 that appears in Proposition is given by: $c_1 = \hat{c}$ whenever $\gamma < 0.94$ and $c_1 = c^-$ otherwise.

Proof of Proposition 3.2

If $c_r \leq c \leq c^M$, the difference between welfare under both the external and the internal scenarios is given by the expression:

$$W_n = \frac{\gamma}{8(2+\gamma)^2(4-3\gamma^2)(4-2\gamma^2+\gamma^3)^2} \left[\begin{array}{l} 256 + 64\gamma - 384\gamma^2 - 16\gamma^3 + 192\gamma^4 - 16\gamma^5 - 32\gamma^6 - \\ -2\gamma^7 + 2\gamma^8 + \gamma^9 + 32c^2\gamma(-4 - 4\gamma + 3\gamma^2 + 3\gamma^3) + \\ + 16c(-32 + 48\gamma^2 - 4\gamma^3 - 22\gamma^4 + 3\gamma^5 + 3\gamma^6). \end{array} \right]$$

We have that W_n is a concave function of c with two roots c^+ and c^- . We have that $c^- < 0$ and $c_r < c^+ < c^M$. Therefore, a merger between the laboratory and firm 1 is welfare improving whenever $W_n \leq 0$. This holds when $c \geq c^+$, where

$$c^+ = \frac{1}{8\gamma(-4-4\gamma+3\gamma^2+3\gamma^3)} \left[\frac{-64 + 96\gamma^2 - 8\gamma^3 - 44\gamma^4 + 6\gamma^5 + 6\gamma^6 + \sqrt{2}}{\sqrt{(8 + 4\gamma - 4\gamma^2 + \gamma^4)^2(32 - 16\gamma - 36\gamma^2 + 16\gamma^3 + 9\gamma^4 - 3\gamma^5)}} \right]$$

When $c > c^M$, in the external case we have the monopoly outcome, whereas in the internal case, outputs do not depend on c because the royalty does not depend on c either. Therefore, the difference in welfare becomes constant in c and amounts to W_n evaluated in $c = c^M$. But we know from the analysis of the previous interval that a merger is welfare

improving at that point, which means that it is also welfare improving in the whole interval.

If $0 \leq c < c_r$, we have that the difference between welfare under both the external and the internal scenarios is given by the expression:

$$W_r = \frac{1}{4(2-\gamma)^2(2+\gamma)^2(4-2\gamma^2+\gamma^3)^2} \left[\begin{array}{l} (2-\gamma)^3\gamma^2(16-10\gamma^2+3\gamma^3+\gamma^4)+ \\ +4c(2-\gamma)^2(16-16\gamma-16\gamma^2+20\gamma^3 \\ +2\gamma^4-6\gamma^5+\gamma^6)+2c^2(64-144\gamma^2+ \\ +32\gamma^3+88\gamma^4-48\gamma^5-8\gamma^6+12\gamma^7-3\gamma^8). \end{array} \right]$$

In order to show that W_r is positive in the whole interval, it is sufficient to check first, that it is a quadratic, continuous function of c , which implies that it is either a convex or a concave function of c ; second, that W_r is positive at both extremes of the interval. When W_r is a concave function of c both points imply that it is positive in the whole interval. When W_r is convex, we have additionally to check that its first derivative is positive at the origin of the interval, which completes the proof.

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