Patent clearinghouse and technology diffusion: what is the contribution of the arbitration agreements? *

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Abstract

One of the acknowledged benefits of patent clearinghouses is that they favor the diffusion of technology. In traditional clearinghouses, patents are usually sold at a pre-set price, bundled in patent pools. Recently, a new form of clearinghouse in the biotech industry has been observed, where patent prices are instead bargained over by the clearinghouse members. Exchange is then guaranteed by arbitration agreements to which the negotiating parties are bound, should their bargaining reach a dead end. This paper assesses the effect on technology diffusion of this new type of patent clearinghouse. We show such arbitration agreements, through their effect on the outside options, may reduce the incentives of a member of the clearinghouse to license to non-members. This entails that the clearinghouse may actually restrict the diffusion of technology.

Keywords: Vertical contract, Arbitration, Nash Bargaining, Patent Clearinghouse.
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1 Introduction

Outside options are consequential in determining the equilibrium contractual terms within a production channel and, therefore, the upstream firm strategy, both in terms of vertical integration and exclusivity (see e.g. Milliou and Petrakis, 2007 and Bacchiega *et al.*, 2018 and the references therein). Usually, this literature assumes that the outside options are given or that they are determined by the out-of-equilibrium interaction among the same set of agents that negotiate the equilibrium agreement(s). In this work, we take an alternative stance and shed light on how arbitration agreements, where a third party sets out the trading terms in case of breakdown in the negotiations, affect the supply decisions of an upstream firm, and can ultimately limit the diffusion of technology. In particular, we consider the case of a patent clearinghouse wherein members are free to negotiate over the terms of trade but are committed to make their technologies accessible to the other members through arbitration agreements should the initial negotiations break down.

Recently, some agricultural biotechnology firms have attempted to foster the diffusion of technology by establishing patent clearinghouses.[1] The largest of these, in number of members, is the *International Licensing Platform for vegetable plant breeding* (ILP vegetable). This clearinghouse has been established by 11 biotechnology firms in 2015 and concerns only vegetable plants.[2] ILP Vegetable can be considered as a prototype of patent clearinghouse in the life science industry (Van Overwalle, 2018). All the members of ILP Vegetable are bound to share their patents on vegetable plants with all the other members that are require them. Yet, ILP Vegetable does not establish *ex ante* the terms of trade, which are in principle negotiated over by the parts.*ILP Vegetable* however intervenes in the case that an agreement on the contractual terms is not reached, by implementing an arbitration agreement.[3] In particular, should the negotiation fail, a board of experts, acting as arbitrators, sets the terms of exchange. Unlike "traditional" patent pools where IP owners license a bundle of patents at a pre-established price, here bilateral negotiations continue to take place over a single license, but if they break down, an arbitrator dictates the trading terms to the contenders.[4] Accordingly, *ILP Vegetable* has a direct impact on the outside option of its members during the bilateral negotiation. In fact, outside the clearinghouse, the firms engaged in the negotiation anticipate that if the bilateral negotiation fails, the firms that need the necessary technology will not produce and/or innovate. Conversely, inside the clearinghouse, even if the bilateral negotiation fails, the agents anticipate that all firms will produce and/or innovate because of

[1] Some examples of patent clearinghouse in other sectors have been studied and presented by Van Zimmeren *et al.* (2006) and Aoki and Schiff (2008).

[2] As of October 2018, there were 13 firms in ILP vegetable covering 219 patents on vegetables.

[3] Arbitration agreements are common in consumer contracts and employment contracts, but they can be included in any contract negotiation.

[4] See Reisinger and Tarantino (2019) for a recent theoretical contribution on patent pools.

the intervention of the arbitrator. This specific feature of *ILP Vegetable* has an impact on the *actual* tariff resulting from the bilateral negotiation between the members of the clearinghouse.

The negotiation and arbitration procedure adopted by *ILP vegetables* raises the fundamental research question concerning the effects of such characteristics on the diffusion of technologies through licensing.

Indeed, it is well-known that an upstream firm (the IP owner, in our setup) can commit to offering an exclusive contract to a downstream firm (the IP user) and thus foreclose other potential licensees. Typically, this is the case if competition among downstream firms is intense, because it becomes profitable to foreclose some downstream firms in order to reduce competitive pressure and consequently to increase the revenue extracted through the licensing contract. Yet, foreclosure is no longer an option inside the clearinghouse, because the IP owner is obliged to license its patented technology to all the members of the clearinghouse requesting it. It can however still foreclose the non-members, thus reducing competition in the downstream sector. It is then of interest to study the behavior of the IP owner with regard to its offer of licenses external to the clearinghouse. Because the members of a clearinghouse are requested to share patented technologies with the other members, patent clearinghouses are usually deemed to be a facilitating factor for knowledge sharing and hence innovation. However, to have a thorough assessment on this point, the patent licensing behavior of the clearinghouse members toward non-members has to be scrutinized as well. Incidentally, our analysis also provides some insights on the related issue of the attractiveness, for a IP owner, to become a member of the clearinghouse.

We delve into the aforementioned research question by means of a four stage model of strategic interaction. An upstream firm, the IP owner, can potentially license its patented technology to two firms. At the first stage, the IP owner decides whether to join a patent clearinghouse where one of the two firms is already member. At the second stage, the IP owner chooses which firm(s) to enter a negotiation with in order to trade its patent. At the third stage simultaneous negotiations take place over the contractual terms of the licence(s). At the fourth and last stage, firms set their output levels and compete in the final market. In our analysis we assume that the IP owner can also use its technology to create and sell its product in the downstream market, as it is typically the case for members of patent clearinghouses.

At the bargaining stage, the fact that the IP owner is, or is not, a member of the patent clearinghouse affects the outside options both of the IP owner and of the potential licensees. If the IP owner is a member of the clearinghouse, in the event of a breakdown in the negotiations, the arbitrator dictates a settlement which maximizes the surplus generated by the compulsory licensing. The arbitrator then apportions the surplus obtained through the bilateral relationship according to the relative weight, in its own preferences, of the IP owner and of the licensee.

Within the patent clearinghouse the presence of the arbitrator affects the terms of trade negotiated between the IP owner and the downstream firms. More precisely, the negotiated royalty rate is unaffected by the IP owner being or not a member of the patent clearinghouse, for a given number of firms active on the final market. By contrast, because the IP owner's choice whether or not to join the clearinghouse affects the outside options at the negotiation stage, it determines how the surplus from the bilateral relationship is apportioned through the fixed fee.

It is worth noting here that, when the IP owner is a member of the clearinghouse, the presence of the arbitrator has a twofold effect on its profits. First, the arbitrator is concerned only by the surplus that is generated by the traded license. Consequently, its ruling does not take into account the profits that the IP owner reaps from its own sales on the downstream market. Because of product substitutability, however, these sales are affected by the royalty rate in the license, which determines the marginal cost of the licensee. This effect, which we label an *externalization effect*, reduces the IP owner's profit in case of arbitration and thus its outside option in the negotiation within the clearinghouse. Second, the apportioning of the surplus created by the patent inside the clearinghouse depends on the relative weight that the IP owner and the licensee have in the arbitrator's preferences. Clearly, the larger the IP owner's weight, the larger its profit in the case of arbitration and thus its outside option in the negotiation within the clearinghouse. We call this effect the *arbitrator's preferences effect*.

We show that if the *arbitrator's preferences effect* is weak, the *externalization effect* prevails, and the IP owner does not benefit from joining the patent clearinghouse. Furthermore, irrespective of its membership of the clearinghouse, if the IP owner has a low bargaining power, it offers an exclusive contract in order to protect its own sales on the downstream market. However due to the *externalization effect* the incentive to offer an exclusive contract can be larger when the IP owner joins the clearinghouse. Then, surprisingly, the IP owner may grant fewer overall licences if it is a clearinghouse member.

The paper is organized as follows. In Section 2 we review the relevant literature. We then present the model in Section 3. In Section 4 we derive the equilibrium contracts and discuss the IP owner's strategies to enter the patent clearinghouse and to offer licences. Section 5 explores the robustness of our results to some extensions. Finally Section 6 concludes.

2 Related literature and contribution

Our paper connects to several strands of literature. First, it contributes to the literature on vertical contracting. A main topic within this literature is the commitment problem that arises for an upstream firm when it trades with multiple downstream firms (see Hart and Tirole, 1990, O'Brien and Shaffer, 1992, McAfee and Schwartz, 1994, and Rey and Vergé, 2004). Though usually, considering negotiations based on a take-it-or-leave-it offers several works adopt a bargaining approach and analyze the role of both bargaining power and outside options on the equilibrium supply structure of the industry. Differently from these contributions, in our setup arbitration follows negotiation breakdown, which affects the outside options both because of the number of active firms and because of the way the terms of trade are set.

In line with this literature, Bacchiega *et al.* (2018) show that the distribution of bargaining power during the contract terms negotiations determines the choices of an upstream monopolist as for both the precontractual arrangements and contract (non-)exclusivity. They argue that the monopolist offers non-exclusive contracts to increase its negotiation power through the outside options if its bargaining power is sufficiently low. In this case, the upstream firm sets the precontractual arrangements in order to maximize the value of these outside options.[5]

In a quite different setup Matsushima and Shinohara (2014) argue that a supplier has incentives to enter non-exclusive relationships when its bargaining power is low. The main driving force behind their result is that the supplier incurs high sunk investment costs to produce the essential input for each downstream firm. In the present paper, we show that an upstream firm, operating in the final goods market, opts for an exclusive contract only when its own bargaining power is low enough as well tough for a completely different reason. For high bargaining power the upstream firm extracts a large part of the downstream profits, whereby it offers non-exclusive licenses. For low bargaining power, however, its ability to extract downstream surplus is reduced, and it is then optimal to foreclose one of the downstream firms in order to relax downstream competition and increase the profits originating from its own good. This incentive toward an exclusive contract may become larger if the upstream firm is a member of the Clearinghouse.

Also in line with this literature, Milliou and Petrakis (2007) show that upstream merger incentives crucially depend on the type of wholesale contracts in place, the distribution of the bargaining power and the level of downstream competition. From a complementary standpoint, Iozzi and Valletti (2014) focus on how the observability of breakdowns influences the contractual terms and the upstream firms' incentives to merge.

Our paper is also connected to the literature on the arbitration. Arbitrators have previously been modeled in the labor economics literature, because they are one possible solution to the frequent disputes between workers, or unions, and employers (see, for example Crawford, 1981; Farber and Bazerman, 1986; Gabuthy and Muthoo, 2018). This literature highlights two types of arbitration. First, conventional arbitration, consisting of a discretionary choice of the arbitrator to resolve the dispute. Second, the final-offer arbitration, where each disputant makes a proposal and the arbitrator chooses one among them. In contrast with this litera-

[5] In a similar set-up Bacchiega *et al.* (2020) show auctioning off a two-part tariff contract may prefered to negotiation by an upstream firm when its bargaining power is low and the final goods are not too differentiated.

ture, we consider the role of the arbitration on multilateral negotiations between upstream and downstream firms.

Finally we contribute to the analysis of patent clearinghouses, which has been paid scant attention, so far. One relevant exception is Aoki and Schiff (2010) who analyze the transaction-costs reducing role of these institutions. In their model the downstream market is represented by a continuum of independent downstream products, and independent upstream IP owners sell licenses in the market for technology, which can be substitutable or complementary. The patent clearinghouse provides information on patents and facilitates licensing, directly reducing transaction costs but can exacerbate the tragedy of the anticommons and thus have averse effects on welfare. In the present paper we are not concerned with the effects of information disclosure by a patent clearinghouse. Rather, we focus on the effect of the arbitration on both the choice whether or not to join a clearinghouse, and whether or not to license the patent outside the clearinghouse.

3 Model

3.1 Firms and demands

Consider an industry where at most three imperfectly substitutable products are available to consumers. Each of these goods is produced by a distinct firm. One of these firms, which we will henceforth label, with a slight abuse of notation, "the upstream (U) firm" owns of a patent for an input which is necessary for the production of the final output. Besides producing its own product this firm may sell the input to two other firms (1 and 2) which then turn it into a final good. A representative consumer is present in this industry. Let G be the set of quantities of goods available for consumption produced by the aforementioned firms and x the quantity of a *numéraire* good. Like Milliou and Petrakis (2007), we assume that the representative consumer is characterized by the following utility function.[6]

$$U(G) = \alpha \sum_{q_i \in G} q_i - \frac{1}{2} \left(\sum_{q_i \in G} q_i^2 + \sum_{\substack{i,j \in G \\ i \neq j}} q_i q_j \right) + x. \tag{1}$$

The inverse demand system generated by the constrained maximization of (1), is

$$p_i = \alpha - q_i - \frac{q_j}{2} - \frac{q_k}{2}, \tag{2}$$

[6] See Bowley (1924), Spence (1976), and Dixit (1979).

if three products are available for consumption, with $i, j, k \in \{U, 1, 2\}, i \neq j \neq k$,

$$p_i = \alpha - q_i - \frac{q_j}{2}, \tag{3}$$

if two products are available, with $i, j \in \{U, 1, 2\}, i \neq j$, and, finally,

$$p_i = \alpha - q_i \tag{4}$$

if one single product is available, with $i \in \{U, 1, 2\}$.

Clearly, which of the above cases is the relevant one depends on how may firms are active in the industry, which, in turn, hinges on the twofold decision of the upstream firm whether or not to license the input (and how many licenses to sell) and whether or not to produce its own good. Here we assume that one of the two firms 1 and 2 –say firm 1– is a member of a *Patent Clearinghouse* (PaC) that firm U may join as well.[7] In this case, the patent owned by firm U in the PaC must be licensed to firm 1, either through a private agreement, or, in the event of disagreement, through the intervention of an *arbitrator*. The arbitrator sets the terms of trade between the parties by maximizing the value of the patent *within the bilateral patent owner-licensee relationship* and then by apportioning the so-generated surplus according to the relative weights of the *IP owner* and of the licensee in the arbitrator's preferences. This implied that, if firm U is a member of the PaC, at least firm 1 is active in the market.

3.2 Timing

The interaction among the firms unravels as follows. At the first stage firm U decides whether to join a PaC of which firm 1 is a member. At the second stage, firm U decides how many licenses to sell.[8] At the third stage the contractual terms governing the trade of licenses are determined through bargaining, with the bargaining power distribution being exogenous: $\mu \in [0, 1]$ for firm U and $(1 - \mu)$ for firm i; within the PaC, in the case of disagreement the arbitrator intervenes and determines the terms of exchange.[9] At the fourth stage both firm U and the firms with an active license set their output levels and reap their profits.

4 Equilibrium

In this section we tackle separately every possible market configuration, distinguishing between the cases where firm U is, or is not, a member of the PaC.

[7] The PaC may also include others members that we assume non active on the considered market.

[8] In case of membership of the PaC, the upstream firm is obviously forced to sell the license at least to firm 1.

[9] In the following we consider conventional arbitration. A final-offer arbitration would impose the arbitrator preferences, which would lead to the same outcome of conventional arbitration.

4.1 Firm U is not a member of the Patent Clearinghouse

Five different options are available to firm U with regards to the production and licensing decisions.

1. Firm U sells no license and produces as a monopolist (option M).
2. Firm U sells one exclusive license and does not produce (option E).
3. Firm U sells one exclusive license and produces (option EP).
4. Firm U sells two non-exclusive licenses and does not produce (option N.)
5. Firm U sells two non-exclusive licenses and produces (option P).

Needless to say, in options 1 and 2 the final market is monopolized, in options 3 and 4 we have a duopoly and in option 5 a triopoly.[10]

Hereafter we analyze in detail options EP and P because they dominate the remaining ones from the standpoint of firm U.[11]

4.1.1 Option EP: Exclusive contract with production by firm U

Let us assume that firm U enters an exclusive negotiation with one firm $i \in \{1, 2\}$ and produces its own good. The profits of the firms are as follows.[12]

$$\Pi_i^p(q_i, q_U, T_i) = q_i w_i + t_i + p_U(q_U, q_i) q_U, \tag{5}$$

$$\pi_i(q_i, T_i) = [p_i(q_U, q_i) - w_i] q_i - t_i, \tag{6}$$

Simultaneous maximization of (5) and (6) with respect to q_U and q_i returns

$$\bar{q}_U(w_i) = \frac{2\alpha}{5} + \frac{2w_i}{15}, \quad \bar{q}_i(w_i) = \frac{2\alpha}{5} - \frac{8w_i}{15}. \tag{7}$$

Plugging them back into the profits yields

$$\bar{\Pi}_i^p(T_i) = \frac{2}{225}\left(18\alpha^2 - 58w_i^2 + 57\alpha w_i\right) + t_i, \quad \bar{\pi}_i^p(T_i) = \frac{4}{225}(3\alpha - 4w_i)^2 - t_i. \tag{8}$$

At the negotiation stage, in case of breakdown the upstream firm can still produce its own product, as a monopolist, reaping a profit equal to $\Pi^M = \frac{\alpha^2}{4}$ (see Appendix A.1). By

[10] In the following, for the sake of readability, we will keep the notation as light as possible, introducing further indexes when unavoidable only.

[11] Appendix A reports the dominated cases.

[12] The subscript i identifies the exclusive contract, while the subscript p refers to the production by firm U.

contrast, the downstream firm cannot produce, and consequently its profit would be nil. The Nash product is, accordingly

$$NP^{EP}(T_i) = \left[\bar{\Pi}_i^p(T_i) - \Pi^M\right]^\mu \left[\bar{\pi}_i^p(T_i)\right]^{1-\mu}. \tag{9}$$

Its maximization w.r.t. w_i and t_i returns (by symmetry we can hereafter drop the index i)

$$T^{EP} \equiv \left\{w^{EP}, t^{EP}\right\} = \left\{\frac{9\alpha}{52}, \frac{1}{169}\alpha^2(13\mu + 3)\right\} \tag{10}$$

As expected, the optimal royalty rate differs from the marginal production cost because firm joint profit maximization requires taking into account of the substitutability between the two final products. By plugging back T^{EP} into the relevant functions we obtain

Lemma 1. *In the case of an exclusive contract with production by firm U, the optimal contractual terms are T^{EP}. Under this contract the optimal quantities are $q_U^{EP} = \frac{11\alpha}{26}$ and $q_i^{EP} = \frac{4\alpha}{13}$. The corresponding optimal prices are $p_U^{EP} = \frac{11\alpha}{26}$ and $p_i^{EP} = \frac{25\alpha}{52}$. The profits of both firms are $\Pi^{EP} = \frac{\alpha^2(13+4\mu)}{52}$ and $\pi_i^{EP} = \frac{\alpha^2(1-\mu)}{13}$. Finally, the consumer surplus is $CS^{EP} = \frac{21\alpha^2}{104}$.*

4.1.2 Option P: Non-exclusive contract with production by firm U.

With this option the upstream firm proposes non-exclusive contracts to the downstream firms, and still produces its own good, which is a substitute of the ones of firms 1 and 2.

The profits of firm 1 and 2 are

$$\pi_i(q_i, q_j, q_U, T_i) = [p_i(q_i, q_j, q_U) - w_i]q_i - t_i, \quad i \in \{1, 2\}, i \neq j, \tag{11}$$

while that of firm U is

$$\Pi(q_1, q_2, q_U, T_1, T_2) = q_U p_U(q_U, q_1, q_2) + q_1 w_1 + q_2 w_2 + t_1 + t_2, \tag{12}$$

where $q_U(\cdot)$ is the demand of product U as defined in (2). The firms' best replies at the quantity setting stage are as follows

$$q_i(q_j, q_U, w_i) = \frac{1}{4}\left(2\alpha - q_j - q_U - 2w_i\right), i, j \in \{1, 2\}, i \neq j, \tag{13}$$

and

$$q_U(q_1, q_2) = \frac{1}{4}\left(2\alpha - q_1 - q_2\right). \tag{14}$$

It is important now to remember that (i) contracts are secret, i.e. firm i does not know the terms of the contract of firm j even after the contract has been finalized, and (ii) that firms have passive beliefs.[13] This has implications for the definition of the profits at the negotiation stage both for firm $i = 1, 2$ and for firm U. We shall start with firm i.

Secret contracts prevent firm $i = 1, 2$ from making its output level contingent on the actual value of the tariff negotiated between the rival firm $j \neq i$ and firm U. A direct consequence is that, in this case, when firm U and firm i bargain over the tariff T_i they do not directly take into account the effect that this tariff has on q_j.[14] This results in the fact that the quantity of firm i depends on the negotiated w_i and on the –anticipated– equilibrium quantity of firm j, $\hat{q}_j^P$, but *not* on w_j. In our setup, firm i has to account for the fact that firm U is active in the product market as well and, thus, that the price of its good, $p_i(\cdot)$, also depends on the quantity set by firm U (besides that of firm j, $\hat{q}_j^P$). By the same token, firm i cannot make the anticipated quantity of U contingent on w_2, because of contract unobservabilty. [15] Consequently the quantity of firm i, and the quantity of firm U, as conjectured by i are

$$\tilde{q}_U(w_i, \hat{q}_j^P) = \frac{1}{15}(6\alpha - 3\hat{q}_j^P + 2w_i), \quad \tilde{q}_i(w_i, \hat{q}_j^P) = \frac{1}{15}(6\alpha - 3\hat{q}_j^P - 8w_i), \tag{15}$$

which have been derived by solving the system defined by (13) and (14) for $q_j = \hat{q}_j^P$.

In order to be consistent with the assumption of secret contracts, we assume that firm U appoints two different agents to negotiate with firms 1 and 2.[16] As a result, at the negotiation stage each agent shares the same conjectures, $\tilde{q}_U(w_i, \hat{q}_j^P)$ and $\tilde{q}_i(w_i, \hat{q}_j^P)$, of the firm $i = 1, 2$ with which they are negotiating.

This said, at the negotiation stage, the profit of the firms are the following.

$$\begin{aligned}\bar{\Pi}_i(\hat{q}_j^P, T_i, T_j) &= \tilde{q}_U(w_i, \hat{q}_j^P) \times p_U(\tilde{q}_U(w_i, \hat{q}_j^P), \tilde{q}_i(w_i, \hat{q}_j^P), \hat{q}_j^P) + \tilde{q}_i(w_i, \hat{q}_j^P) \times w_i + \hat{q}_j^P w_j + t_i + t_j = \\ &= \frac{1}{225}\left(36\alpha^2 + 3\hat{q}_j^P(3\hat{q}_j^P - 19w_i - 12\alpha) - 116w_i^2 + 114w_i\alpha\right) + \hat{q}_j^P w_j + t_i + t_j,\end{aligned} \tag{16}$$

and

$$\bar{\pi}_i(\hat{q}_j^P, T_i) = \tilde{q}_i(w_i, \hat{q}_j^P) \times \left[p_i(\tilde{q}_U, \tilde{q}_i, \hat{q}_j^P) - w_i\right] - t_i = \frac{(6\alpha - 3\hat{q}_j^P - 8w_i)^2}{225} - t_i, i \in \{1, 2\}, i \neq j. \tag{17}$$

[13]Under passive beliefs, when a firm receives an offer different from what it expects, it does not revise its beliefs about the offers made to others firms (McAfee and Schwartz, 1994). Passive beliefs are convenient in that they are usually easy to study (see e.g. O'Brien and Shaffer, 1992; McAfee and Schwartz, 1994), but in addition they are natural when the downstream competition is Cournot-like (see Hart and Tirole, 1990 and Rey and Vergé, 2004).

[14]See O'Brien and Shaffer, 1992; Rey and Vergé, 2004.

[15]We assume that i knows the marginal production cost of U, namely zero.

[16]This assumption of "delegated agent" is in line with the passive beliefs assumption (see McAfee and Schwartz, 1994), and with the concept of *Nash in Nash bargaining* (see Collard-Wexler *et al.*, 2019).

If the negotiation fails, downstream firms cannot use the patented technology, so their profits would be zero and as would their outside options. By contrast, when negotiation fails with the downstream firm i, the upstream firm still expects the negotiation to go ahead successfully with the downstream firm j. As a consequence, the outside option of the upstream monopolist, when it negotiates with firm i, is the profit it would reap in an exclusive relationship with firm j.[17] Accordingly, the Nash products write

$$NP_i(\hat{q}_j^P, T_i, T_j) = \left[\bar{\Pi}_i(\hat{q}_j^P, T_i, T_j) - \bar{\Pi}_j^p(T_j)\right]^{\mu} \left[\bar{\pi}_i(\hat{q}_j^P, T_i)\right]^{1-\mu}, \quad i \in \{1,2\}, i \neq j, \tag{18}$$

where $\bar{\Pi}_j^p(T_j)$ is as in (8). Simultaneous maximization of these expressions yields the following optimal tariffs.[18]

$$T_i^P \equiv \{w_i^P, t_i^P\} = \left\{\frac{3\alpha}{20}, \frac{8\alpha^2(43\mu+7)}{5625}\right\}, \quad i \in \{1,2\}. \tag{19}$$

Interestingly, although contracts are not observable for the downstream firms, the fact that the upstream firm is actually producing generates an increase in the royalty rates. This is due to the fact that when T_i is bargained over, firms U and i considers the effect of T_i on downstream competition through the effect of w_i on $\tilde{q}_U(w_i, w_j)$.

By plugging the optimal tariff into the relevant functions we state:

Lemma 2. *In the case of a non-exclusive contract with production by firm U, the equilibrium contracts are T_i^P. Equilibrium prices are $p_1^P = p_2^P = \frac{5\alpha}{12}$, $p_U^P = \frac{11\alpha}{30}$ and quantities are $q_1^P = q_2^P = \frac{4\alpha}{15}$ and $q_U^P = \frac{11\alpha}{30}$. The profits of the upstream and the downstream firms are $\Pi^P = \frac{\alpha^2(2752\mu+5273)}{22500}$ and $\pi_1^P = \pi_2^P = \frac{344\alpha^2(1-\mu)}{5625}$, respectively. The consumer surplus is $CS^P = \frac{163\alpha^2}{600}$.*

4.1.3 Optimal choice

Proceeding by backward induction we examine the choice of production and (non-)exclusivity of firm U if it is not a member of the PaC. Option EP dominates both options E and M and option P dominates option N (see Appendix A). Being left with options P and EP only, we immediately observe that $\Pi^{EP} \gtreqless \Pi^P \Leftrightarrow \mu \lesseqgtr 0.3447$. We claim:

Lemma 3. *When firm U is not a member of the PaC, it opts for*

(i) producing its own good and offering an exclusive contract for $\mu \in [0, 0.3447]$,

(ii) producing its own good and offering non-exclusive contracts for $\mu \in [0.3447, 1]$.

[17] Here we will assume that contracts are not contingent, so that the equilibrium contractual terms are the same along and off the equilibrium path.

[18] It is easy to prove that in our setup, as firms compete in Cournot, the impact of a multilateral deviation is the sum of the impacts of each unilateral deviation, implying that our contract equilibrium exists (Rey and Vergé, 2004).

4.2 Firm U is a member of the Patent Clearinghouse

We now move to the case where Firm U is a member of the PaC, which affects the previous analysis for two reasons. First, membership of the PaC modifies the members' outside options, which now depend on their relative weights in the arbitrator's preferences and not only on the profits that can be reaped outside the relationship. Second, and related to the previous point, within the PaC trade always occurs, which means that firm 1 (the one already in the PaC) is always active in the final market, *both on and off the equilibrium path.* A direct consequence of this is that the set of possible equilibrium configurations is restricted w.r.t. the case of PaC and are the following

1. Firm U sells one license and does not produce (option EC).
2. Firm U sells one license and produces (option EPC).
3. Firm U sells two licenses and does not produce (option NC).
4. Firm U sells two licenses and produces (option PC).

As argued above, in the case of disagreement on the licensing terms between firm U and 1, the arbitrator settles the issue by selecting the royalty rate that maximizes the value of the patent sales *given* the output choices of the active firms. It subsequently apportions that revenue according to some exogenous weight depending on the arbitrator's relative preferences for firms U and 1. In the following let $\eta \in [0,1]$ be the weight of firm U and $1-\eta$ that of firm 1. The parameter η captures the type of arbitrator and can be viewed as a measure of the importance of the IP owner in the arbitrator's preferences, implying that this importance is increasing in η.

As above, we hereafter present only options EPC and PC because they dominate the remaining ones, which are relegated to Appendix B.

4.2.1 Option EPC: Exclusivity and production by firm U

Membership of the clearinghouse by firm U modifies the outside options of the firms at the negotiation stage only. As a consequence equations (5) to (8) hold unchanged compared to option EP. To determine the Nash product, however, the new outside options for the firms have to be defined. The total value of licensing the patent is given by $p_1(\bar{q}_U(w_1), \bar{q}_1(w_1)) \times \bar{q}_1(w_1) = \frac{2}{225}(3\alpha - 4w_1)(6\alpha + 7w_1)$, which is maximized for $w_1 = -\frac{3\alpha}{56}$. Interestingly the arbitrator, who is not concerned by the sales of firm U's product, would impose here a *negative* royalty rate to boost the sales of the product sold under the PaC agreement, at the expenses of firm U's own product. At this royalty rate the sales of good 1 are $\bar{q}_1(-\frac{3\alpha}{56}) = \frac{3\alpha}{7}$ and its price $\frac{3\alpha}{8}$, returning a total value for the license of $\frac{9\alpha^2}{56}$, of which a fraction η accrues to firm U and the complementary fraction $1-\eta$ to firm 1. The outside option of firm U in the negotiation with 1 includes the fraction η of the value of the license as determined by the arbitrator, but also the value of the sales of good U for $w_1 = -\frac{3\alpha}{56}$ and given by:

$$\bar{q}_U(w_1) \times p_U(\bar{q}_U(w_1), \bar{q}_1(w_1) = \frac{121\alpha^2}{784} \tag{20}$$

This clarified, the Nash product is

$$NP^{EPC}(T_1) = \left[\bar{\Pi}^p(T_1) - (\frac{121\alpha^2}{784} + \eta\frac{9\alpha^2}{56})\right]^\mu \left[\bar{\pi}_1^p(T_1) - (1-\eta)\frac{9\alpha^2}{56}\right]^{1-\mu}. \tag{21}$$

Besides the difference in the value of the outside option from firm U, it should be noticed that, the membership of the PaC allows firm 1 to bargain with a positive outside option as compared to case EP. By maximizing the Nash product w.r.t. T_1, we get

$$T_1^{EPC} \equiv \left\{w_1^{EPC}, t_1^{EPC}\right\} = \left\{\frac{9\alpha}{52}, \frac{\alpha^2(21294\eta + 1573\mu - 10323)}{132496}\right\}. \tag{22}$$

By substituting the optimal tariff value back into the relevant functions, we obtain

Lemma 4. *In the case of an exclusive contract with production by firm U, the optimal contractual terms are T^{EPC}. Under this contract the optimal quantities are $q_U^{EPC} = \frac{11\alpha}{26}$ and $q_1^{EPC} = \frac{4\alpha}{13}$. The corresponding optimal prices are $p_U^{EPC} = \frac{11\alpha}{26}$ and $p_1^{EPC} = \frac{25\alpha}{52}$. The profits of both firms are $\Pi^{EPC} = \frac{\alpha^2(1638\eta+121\mu+1249)}{10192}$ and $\pi_1^{EPC} = \frac{\alpha^2(1759-1638\eta-121\mu)}{10192}$. Finally, the consumer surplus is $CS^{EPC} = \frac{21\alpha^2}{104}$.*

4.2.2 Option PC: Non-exclusivity and production by firm U

The quantity setting stage of option PC overlaps with that of option P, hence equations (11) to (17) are the same. As before, the difference is in the definitions of the outside options for the firms in the PaC, as those of the negotiation between U and 2 are unaffected by the presence of the PaC. The outside option for firm U depends both on the arbitrator's decision and on the profit this firm can reap from the sales of its own product and of the license to firm 2. The outside option of firm 1, instead, depends only on the arbitrator's ruling. We shall start by characterizing the choices of the arbitrator in the case of breakdown in the negotiation within the clearinghouse.

The arbitrator maximizes the value of the license, given the production choices of firms U and 1 (and 2) and the information available to the firms. This is achieved by choosing the royalty rate that maximizes

$$\tilde{q}_1(w_1,\hat{q}_2^{PC})\times p_1(\tilde{q}_U(w_1,\hat{q}_2^{PC}),\tilde{q}_1(w_1,\hat{q}_2^{PC}),\hat{q}_2^{PC})=\frac{1}{225}(6\alpha-3\hat{q}_2^{PC}+7w_1)(6\alpha-3\hat{q}_2^{PC}-8w_1), \tag{23}$$

that is to say, $\tilde{w}_1=\frac{3}{112}(-2\alpha+\hat{q}_2^{PC})$. As before, because the equilibrium quantity of firm 2 is always less than α, the royalty rate maximizing the value of the license is negative. The reason is that the arbitrator aims at boosting the sales of good 1, without taking into account the effects on goods U and 2. At $\tilde{w}_1$, the value of the license amounts to $\frac{9(2\alpha-\hat{q}_2^{PC})^2}{224}$.

Outside options of U in the negotiation with 1. The outside option of firm U in the negotiation with 1 includes the fraction η of the value of the license as determined by the arbitrator, as well as the sum value of the sales of good U and the revenue from the licensing contract with firm 2. The latter two terms are, respectively

$$\tilde{q}_U(\tilde{w}_1,\hat{q}_2^{PC})\times p_U(\tilde{q}_U(\tilde{w}_1,\hat{q}_2^{PC}),\tilde{q}_1(\tilde{w}_1,\hat{q}_2^{PC}),\hat{q}_2^{PC})=\frac{121(2\alpha-\hat{q}_2^{PC})^2}{3136} \tag{24}$$

and

$$\hat{q}_2^{PC}w_2+t_2. \tag{25}$$

Consequently, the outside option of firm U in the negotiation with firm 1 amounts to

$$\bar{\Omega}_1^{PC}(\hat{q}_2^{PC},T_2)\equiv\frac{121(2\alpha-\hat{q}_2^{PC})^2}{3136}+\hat{q}_2^{PC}w_2+t_2+\eta\frac{9(2\alpha-\hat{q}_2^{PC})^2}{224}. \tag{26}$$

Outside option of 1 in the negotiation with U. In case the negotiation between U and 1 breaks down, the agreement implemented by the arbitrator guarantees firm 1 an amount equal to

$$\bar{\omega}_1(\hat{q}_2^{PC})=(1-\eta)\frac{9(2\alpha-\hat{q}_2^{PC})^2}{224}. \tag{27}$$

Outside option of U in the negotiation with 2. In this case the outside option for firm U is its profit in the option EPC. However, because of the assumption of non-contingent contracts, the royalty rate is the same along and off the equilibrium path. Accordingly, the outside option is $\bar{\Pi}^p(T_1)$. Note that, at the candidate equilibrium, this outside option is different from Π^{EPC}.

The observation that the outside option for firm 2 is zero concludes the description of the set of outside options for the firms, and enables us to write down the Nash products at the bargaining stage, which are

$$NP_1^{PC}(\hat{q}_2^{PC}, T_1, T_2) = \left[\bar{\Pi}_1(\hat{q}_2^{PC} T_1, T_2) - \bar{\Omega}_1(\hat{q}_1^{P}, \hat{q}_2^{PC}, T_2)\right]^{\mu} \left[\bar{\pi}_1(\hat{q}_2^{PC}, T_1) - \bar{\omega}_1(\hat{q}_2^{PC})\right]^{1-\mu}, \tag{28}$$

and

$$NP_1^{PC}(\hat{q}_2^{PC}, T_1, T_2,) = \left[\bar{\Pi}(T_1, T_2) - \bar{\Pi}^{p}(T_1)\right]^{\mu} \left[\bar{\pi}_2(\hat{q}_1^{PC}, T_2)\right]^{1-\mu}. \tag{29}$$

Simultaneous maximization of the two above expressions w.r.t. T_1 and T_2 yields

$$T_1^{PC} \equiv \left\{w_1^{PC}, t_1^{PC}\right\} = \left\{\frac{3\alpha}{20}, \frac{\alpha^2(21294\eta + 1573\mu - 10323)}{176400}\right\}, \tag{30}$$

and

$$T_2^{PC} \equiv \left\{w_2^{PC}, t_2^{PC}\right\} = \left\{\frac{3\alpha}{20}, \frac{8\alpha^2(43\mu + 7)}{5625}\right\}. \tag{31}$$

By putting of the optimal tariffs back into quantities, prices, profits and consumer surplus we can state:

Lemma 5. *In the case of a non-exclusive contract with production by firm U, the optimal contractual terms are $T_i^{PC}, i = \{1, 2\}$. Under these contracts the optimal quantities are $q_U^{PC} = \frac{11\alpha}{30}$ and $q_i^{PC} = \frac{4\alpha}{15}$. The corresponding optimal prices are $p_U^{PC} = \frac{11\alpha}{30}$ and $p_i^{PC} = \frac{5\alpha}{12}$. The firms' profits are $\Pi^{PC} = \frac{\alpha^2(243843+177450\eta+103007\mu)}{1470000}$, $\pi_1^{PC} = \frac{13\alpha^2(1759-1638\eta-121\mu)}{176400}$ and $\pi_2^{PC} = \frac{344\alpha^2(1-\mu)}{5625}$. Finally, the consumer surplus is $CS^{PC} = \frac{163\alpha^2}{600}$.*

4.2.3 Optimal choices

Proceeding by backward induction we tackle firm U's choice to offer or not exclusivity and whether to produce or not when firm U is a member of the PaC. Option EC is dominated by option EPC as $\Pi^{EPC} > \frac{\eta\alpha^2}{4}$, just as option NC is dominated by option PC as $\Pi^{PC} > \Pi^{NC}$. It is a matter of simple algebra to ascertain that $\Pi^{PC} > \Pi^{EPC} \Leftrightarrow \mu \in [0.4889, 1] \cup \{\mu \in [0, 0.4889] \cap \eta \in [0, (1.4550\mu + 0.2886)]\}$ and $\Pi^{PC} < \Pi^{EPC} \Leftrightarrow \mu \in [0, 0.4889] \cap \eta \in [(1.4550\mu + 0.2886), 1]$.

Lemma 6. *When firm U is a member of the PaC, it opts for*

(i) producing its own good and offering an exclusive contract for $\mu \in [0, 0.4889]$ and $\eta \in [(1.4550\mu + 0.2886), 1]$

(ii) producing its own good and offering a non-exclusive contract for (a) $\mu \in [0.4889, 1]$ or (b) $\mu \in [0, 0.4889]$ and $\eta \in [0, (1.4550\mu + 0.2886)]$

4.3 Discussion

Having obtained all the expressions for the equilibrium strategy according to type of firm U (member or not of the PaC), we can now sum up and answer our research questions about: i) firm U's strategies to enter the PaC; and ii) the number of licences offered.

The following Proposition describes the optimal choices of firm U concerning the membership of the PaC and the number of licenses to sell. Figure 1 diagrammatically reports its results.

Proposition 1. *Firm U opts for*

(i) An exclusive contract without joining the PaC (option EP) for

(a) $\mu \in [0, 0.2920] \cap \eta \in [0, (0.4048\mu + 0.5952)]$,

(b) $\mu \in [0.2920, 0.3447] \cap \eta \in [0, (0.0567\mu + 0.6968)]$.

(ii) A non-exclusive contract without joining the PaC (option P) for

$$\mu \in [0.3447, 1] \cap \eta \in [0, (0.4327\mu + 0.5672)].$$

(iii) An exclusive contract joining the PaC (option EPC) for

(a) $\mu \in [0, 0.2920] \cap \eta \in [(0.4048\mu + 0.5952), 1]$,

(b) $\mu \in [0.2920, 0.4889] \cap \eta \in [(1.4550\mu + 0.2886), 1]$.

(iv) A non-exclusive contract joining the PaC (option PC) for

(a) $\mu \in [0.2920, 0.3447] \cap \eta \in [(0.0567\mu + 0.6968), (1.4550\mu + 0.2886)]$,

(b) $\mu \in [0.3447, 0.4889] \cap \eta \in [(0.4327\mu + 0.5672), (1.4550\mu + 0.2886)]$,

(c) $\mu \in [0.4889, 1] \cap \eta \in [(0.4327\mu + 0.5672), 1]$.

Proof. Follows from direct comparison of the profit levels of firm U. □

The ensuing result directly follows from the preceding Proposition.

Corollary 1. *Irrespectively of being a member or not of the PaC, firm U i) always produces its own good, and ii) offers non-exclusive contracts (respectively exclusive contracts) if its bargaining power is sufficiently high (respectively low).*

As the IP owner produces its own variant, the larger the number of active firms, the lower the profit from the sales of its own variant, because of increased competition in the downstream market. The IP owner therefore offers non-exclusive contracts –thereby increasing the competitive pressure in the product market– only when it can compensate for that loss

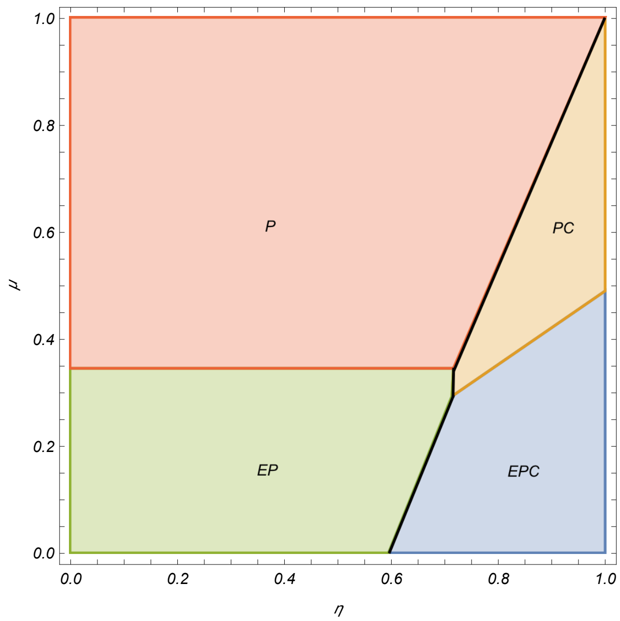


Figure 1: Equilibrium choices in the $\eta - \mu$ space.

in profit through a large extraction of the profit of firms 1 and 2, namely when its bargaining power is large. On the other hand, if its bargaining power is low, the IP owner prefers to offer an exclusive contract in order to restrain downstream competition and thus increase the profit coming from its own product. This should be contrasted with Bacchiega *et al.* (2018), who, in a setup where the IP owner is not active in the final market, show that the IP owner offers non-exclusive contracts (respectively exclusive contracts) for a low (respectively high) value of bargaining power. In that paper, non-exclusive contracts increase the IP owner's negotiation power by improving its outside options.

Another immediate result yielded by the foregoing Proposition, which relates to the attractiveness of the Clearinghouse for the IP owner, is:[19]

Corollary 2. *A weight in the arbitrator's preferences larger than its own bargaining power ($\eta > \mu$) is a necessary but not sufficient condition for firm U to join the PaC.*

[19] As our paper focuses on arbitration agreements, it is of interest to assess how they affect the attractiveness to join the clearinghouse. Here we disregard the obvious case where the firm considering to enter the clearinghouse aims at obtaining licenses for patents owned by clearinghouse members.

Proof. By Proposition 1 the minimum value of η for which Firm U joins the PaC is

$$\underline{\eta} = \begin{cases} (0.4048\mu + 0.5952) \text{ for } \mu \in [0, 0.2920], \\ (0.0567\mu + 0.6968) \text{ for } \mu \in [0.2920, 0.3447], \\ (0.4327\mu + 0.5672) \text{ for } \mu \in [0.3447, 1]. \end{cases}$$

Clearly, $\underline{\eta}$ is always larger than μ. □

This result is driven by two forces that the trade terms dictated by the arbitrator have on the outside option of firm U. The first one is determined by how favorable to firm U the arbitrator's ruling is in the case of disagreement. The more favourable it is, the larger the outside option of that firm within the PaC, and hence the incentive of U to join the PaC itself. We label this *arbitrator's preference effect*, which is clearly increasing in η. Recall now that the outside option of firm U, *if not a member of* the PaC is increasing in μ.[20] Therefore, all else being equal, $\eta > \mu$ is a necessary condition for firm U to join the PaC. Yet, this is not a sufficient condition, because the choice by the arbitrator does not internalize the effect of w_i on the profit of firm U accruing from the sales of its own product q_U. This is reflected by the fact that, as mentioned above, while the (subgame) equilibrium royalty rates are always positive, those set off-equilibrium by the arbitrator are negative. This ultimately reduces the value of the outside option of firm U in the negotiation within the PaC and discourages firm U from joining the PaC itself. It is worth noticing here that the size of this *externalization effect* is independent of η. However, its relative impact on the decision whether or not to join the PaC decreases the larger η in the negotiation, for given μ. Indeed, the larger η is, the larger the share will be of the off-equilibrium profit that firm U appropriates, which will counter the negative effect of not internalizing the effect of w_i on $p_U q_U$ in the outside option. Because the arbitrator's preference effect increases in η and the relevance of the externalization effect decreases in that parameter, a larger η, for given μ, increases the attractiveness for firm U of joining the PaC.

We are now in position to state our main result.

Proposition 2. *In region* $\mu \in [0.3447, 0.4889] \cap \eta \in [(1.4550\mu + 0.2886), 1]$*, the presence of the PaC*

(i) Restricts the number of licenses sold at equilibrium.

(ii) Reduces the surplus of consumers.

Proof. In the region under scrutiny,

[20] Contracts are not contingent.

(i) In the absence of a PaC, by Lemma 3 firm U chooses to sell two licenses, whereas, in the presence of a PaC, by Lemma 6 it opts for an exclusive license only.

(ii) $CS^P = \frac{163\alpha^2}{600} > \frac{21\alpha^2}{104} = CS^{EPC}$

$\square$

For low values of μ the IP owner always offers an exclusive contract in order to optimize the gains on the sales of its own downstream product (see Proposition 1), whether or not it is a member of the clearinghouse. However due to the *externalization effect* the incentive to offer an exclusive contract may be larger when the IP owner joins the clearinghouse. Then, paradoxically, allowing firms to establish a patent clearinghouse can restrain the total number of licenses actually granted, compared to a situation without a patent clearinghouse. This the case of the region (-) in Figure 2, which represents the area identified in Proposition 2.

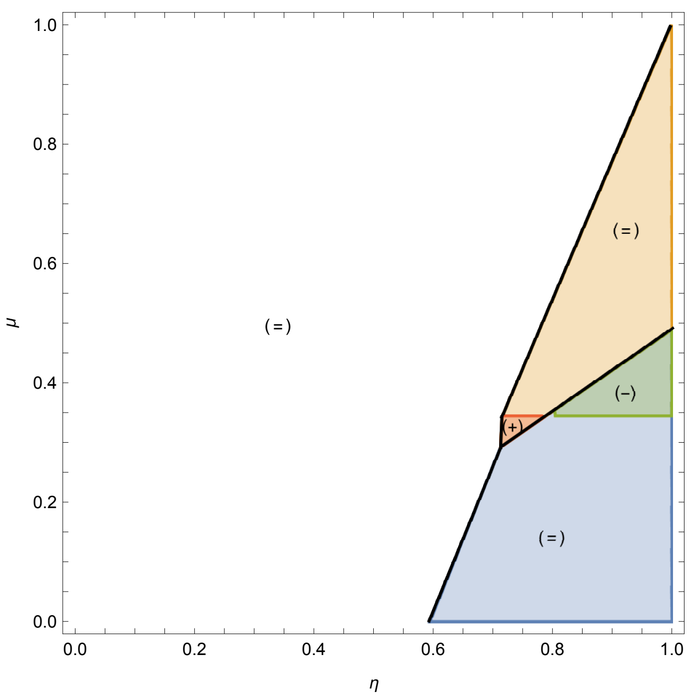


Figure 2: Effect on the number of licenses available of the presence of the PaC.

Two immediate results following Proposition 2 are :

Corollary 3. *In region* $\mu \in [0.2920, 0.3447] \cap \eta \in [(0.0567\mu + 0.6968), (1.4550\mu + 0.2886)]$, *the presence of the PaC, increases the number of licenses sold and the surplus of consumers.*

As pointed out in this last result, the presence of the PaC may also lead to the expected outcome of an increase of the number of licenses actually granted compared to a situation without a patent clearinghouse. This result is driven by the *arbitrator's preference effect*. This is the case of the region (+) in Figure 2, which depicts the area identified in Corollary 3.

Corollary 4. *In all parameter regions not mentioned in Proposition 2 and in Corollary 3, the presence of the PaC does not affect the number of licenses granted or the consumer surplus.*

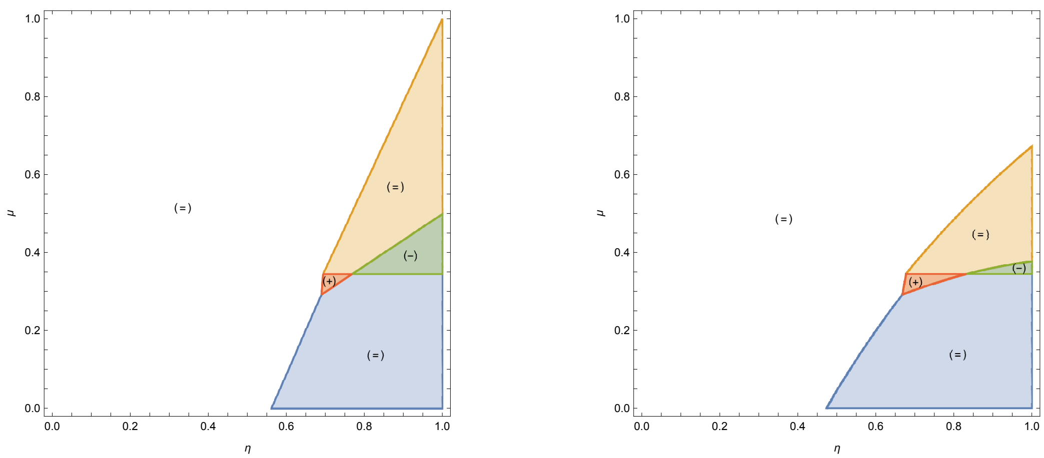
Finally as reported in the previous corollary, the presence of a patent Clearinghouse may also have no effect on the number of licences provided, either because the IP owner does not join the clearinghouse, or because the IP owner joins the clearinghouse but grants the same number of licences as in a situation without a patent clearinghouse. This the case of regions (=) in Figure 2, which represents the areas identified in Corollary 4.

5 Alternative arbitration pricing schemes

In the foregoing sections we carried out our analysis by assuming that the arbitrator implements non-linear contracts based on two-part tariffs. A legitimate question that can arise at this point is about the extent to which our insights are robust if the arbitrator is constrained to use different, less sophisticated, tariff structures. We may prove that our results remain qualitatively unchanged under two alternative and commonly used payment schemes: a lump-sum transfer and a linear fee. Here we will limit our discussion to the main features of these two extensions.[21] Figure 3 reports these two cases. Two remarks are worth making here, which will be helpful in the ensuing discussion. The first one is that –as in the main model– in either extension the IP owner always produces its own good. The second one regards the fact that alternative pricing schemes affect only the outside options of the firms in the platform. This, in turn, entails that the equilibrium two-part tariffs governing the trade between firm U and firm 1 are modified only in the fixed fee, as the royalty rate remains the same as in the main text. The ultimate consequence is, therefore, that the equilibrium prices, quantities and total surplus generated in the industry do not depend on the pricing scheme applied by the arbitrator, which affects only the equilibrium apportioning of the surplus generated by the sales of good 1 between firm U and firm 1 itself. With this in mind, let us consider the two alternative tariff schemes.

The case where the arbitrator uses a lump sum transfer is equivalent to the situation analyzed in the main text, with the royalty rate in case of disagreement equal to zero. Now, remember that, because the arbitrator aims at maximizing the value of the license only, when it applies a two-part tariff it sets a negative royalty rate, in order to boost the sales of good 1. As mentioned above, this royalty rate is too low from the standpoint of firm U. Consequently,

[21] For a detailed analysis see the supplementary appendix.



(a) Lump-sum Tariff

(b) Linear Tariff

Figure 3: Alternative pricing schemes.

the use by the arbitrator of a lump sum transfer, which implicitly amounts to increasing the royalty rate as compared to the two-part tariff, makes product 1 relatively less competitive than product U and increases the outside option of firm U at the expenses of that of firm 1. Eventually, this results in higher equlbrium profits for firm U than in the two-part tariff case. Yet, the *externalization effect* is still at work with a lump-sum tariff, because, the –implicit– royalty rate under a lump sum although higher than the one under the arbitrated two-part tariff, still falls short of the one maximizing the joint profit of firms U and 1. Therefore, for given η and μ, firm U finds it more attractive to join the PaC if the arbitrator uses a lump-sum transfer than if it uses a two-part tariff.

Let us now consider the use of linear tariffs in the case of a disagreement between the parties. It is well-known that, in this setup, the royalty rate both determines the total surplus to be shared and the apportioning thereof, and that the efficiency of linear tariffs within the vertical hierarchy is lower than that of non-linear contracts. It is clear that if it had the power to set the royalty rate, firm 1 would select the lowest rate acceptable to firm U, namely zero, whereas, in the opposite situation, firm U would choose the one maximizing its own profit, we label this royalty rate $w^U > 0$.[22] Clearly the arbitrator must choose a value between these two extremes, and accordingly, we assume that the chosen royalty rate is a weighted average of these extremes, with weights equal to the preference of the arbitrator for the firms, namely $\eta \times w^U + (1 - \eta) \times 0$. An immediate consequence is that, for any $\eta < 1$ the arbitrated royalty rate is lower than the one which fully internalizes the effect on the profits of firm U, which results in the existence of the *externalization effect*. Interestingly, in this case the actual size of this effect is negatively correlated with η. Consequently, the attractiveness of joining the

[22] w^U may be a function of the equilibrium quantity of firm 2, in the case of non-exclusive contracts.

PaC for firm U is larger under linear contracts than under two-part tariffs only if η is large enough.

6 Conclusion

In this paper we have analyzed the consequences of arbitration in a clearinghouse on technological diffusion outside the clearinghouse. We have highlighted two forces that characterize the equilibrium choices: the *arbitrator's preference effect* and the *externalization effect*. Our analysis shows that in the presence of arbitration a platform may actually hamper the diffusion of new technology through licensing by limiting the willingness of the IP owner to license outside the platform. More in detail the presence of the patent clearinghouse may be immaterial to the number of licenses granted, either because the IP owner does not find it advantageous to join the clearinghouse, or because the IP owner joins it but grants the same number of licences as in the absence of a patent clearinghouse. More strikingly, if the IP owner joins the clearinghouse it is possible that the overall number of licenses actually granted is lower than in a situation without a patent clearinghouse, because in this case the IP owner refuses to license outside the platform. In fact, if the *externalization effect* is strong enough the incentive to offer an exclusive contract is larger if the IP owner is a member of the clearinghouse. The former depends on how favorable to the IP owner the arbitrator's ruling is in the case of disagreement. The latter is due to the fact that the arbitrator's terms of trade do not internalize the IP owner's profit stemming from its own downstream product.

Our analysis suits well some recent developments in the agricultural biotechnology sector, where a new patent clearinghouse, the *International Licensing Platform for vegetable plant breeding* (ILP vegetable) has recently been established (see https://www.ilp-vegetable.org/). Its stated mission is to improve the diffusion of technology in the vegetable breeding industry. This platform, which can be considered a patent clearinghouse prototype in the life science industry, is innovative insofar as it introduces an arbitrator who dictates a "fair" sharing agreement between IP-owners and -users in cases where the negotiations between them reach a dead end.

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Appendices

A No PaC: dominated options

A.1 Option M: No license sold

In this option the relevant demand is (4), with $i = U$. Let Π represent the profit of firm U. Basic computations return, in this option

$$q^M = \frac{\alpha}{2}, \quad p^M = \frac{\alpha}{2}, \quad \Pi^M = \frac{\alpha^2}{4}. \tag{32}$$

From direct comparison of Π^M and Π^{EP}, option M is dominated by option EP for firm U.

A.2 Option E: Exclusive contract and no production by firm U

Firm U enters an exclusive relationship with firm $m = 1$ or 2, governed by the two-part tariff contract $T_m = \{w_m, T_m\}$, where w_m is the royalty rate and T_m is the fixed fee. Profits for firms U and 1 are, respectively

$$\Pi_m(q_m, T_m) = q_m w_m + t_m, \tag{33}$$

$$\pi_m(q_m, T_m) = [p_m(q_m) - w_m]q_m - t_m, \tag{34}$$

where the inverse demand $p_m(q_m)$ is as in (4) with $m = 1$ or 2. At the last stage, Firm 1 maximizes its own profit, given T_m by setting

$$\overline{q}_m = \frac{1}{2}(\alpha - w_m). \tag{35}$$

Substituting back (35) into (33) and (34) returns

$$\overline{\Pi}_m(T_m) = \frac{1}{2}w_m(\alpha - w_m) + t_m, \tag{36}$$

$$\overline{\pi}_m(T_m) = \frac{1}{4}(\alpha - w_m)^2 - t_m. \tag{37}$$

At the bargaining stage, the upstream and the downstream firms negotiate over the terms of the contract, with exogenously given bargaining powers. As the upstream firm has committed to an exclusive relationship, if the negotiation fails both upstream and downstream firms would have nil profits which implies that their outside options are zero too. Accordingly, the Nash product is

$$NP^E(T_m) \quad = \quad [\overline{\Pi}(T_m)^\mu[\overline{\pi}_m(T_m)]^{1-\mu}, \tag{38}$$

where μ (res. $1-\mu$) is the bargaining weight of the upstream (res. downstream) firm. Maximization of the Nash product with respect to T_m leads to

$$T^E \equiv \{w^E, t^E\} = \{0, \frac{\alpha^2\mu}{4}\}. \tag{39}$$

As standard, in this case the optimal tariff maximizes the surplus of the production channel by setting the royalty rate equal to the upstream marginal production cost, and then apportions the surplus so generated according to the bargaining power distribution. We can state

Lemma 7. *Under exclusive contract, Equation (39) represents the equilibrium tarification. Substituting the equilibrium tariff into price and quantity yields* $p^E = q^E = \frac{\alpha}{2}$. *The profit of the upstream and the downstream firms are* $\Pi^E = \frac{\alpha^2(\mu)}{4}$ *and* $\pi^E = \frac{\alpha^2(1-\mu)}{4}$, *respectively. The consumer surplus becomes* $CS^E = \frac{\alpha^2}{8}$.

From direct comparison of Π^M and Π^E, the option E is (weakly) dominated by choice M for firm U.

A.3 Option N: Non-exclusive contract and no production by firm U

The upstream firm offers two licenses, but does not produce. In this case the profits of the firms are

$$\Pi(q_1, q_2, T_1, T_2) = q_1 w_1 + q_2 w_2 + t_1 + t_2, \tag{40}$$

$$\pi_i(q_i, q_j, T_i) = [p_i(q_i, q_j) - w_i]q_i - t_i, \quad i \in \{1,2\}, i \neq j, \tag{41}$$

where $p_i(q_i, q_j)$ is the inverse demand of firm i, as in (3).

Because contracts are not observable, firms cannot condition their output choices on the actual value of the tariff negotiated over between the rival and the upstream firm. A direct consequence is that, in this case, when firm U and -say- firm 2 bargain over the tariff T_2 they do not directly take into account the effect that this tariff has on q_1.[23] By plugging the quantity best reply $q_i(\hat{q}_j^N, w_i) = \frac{1}{4}(2\alpha - 2w_i - \hat{q}_j^N)$ of firm $i \in \{1,2\}$, evaluated at the equilibrium quantity from firm j, $\hat{q}_j^N$, back in (40) and (41), we get

$$\overline{\Pi}_i(\hat{q}_j^N, T_1, T_2) = \frac{1}{4} w_1(2\alpha - 2w_i - \hat{q}_j^N) + w_j \hat{q}_j^N + t_i + t_j, \tag{42}$$

$$\overline{\pi}_i(\hat{q}_j^N, T_i) = \frac{1}{16}(2\alpha - 2w_i - \hat{q}_j^N)^2 - t_i, \quad i \in \{1,2\}, i \neq j. \tag{43}$$

[23] See O'Brien and Shaffer, 1992

If the negotiation fails, downstream firms cannot use the patented technology, thus their profits would be zero and so are their outside options. On the contrary, when negotiation fails with the downstream firm i, the upstream firm still expects that the negotiation goes ahead successfully with the downstream firm j. As a consequence, the outside option of the upstream monopolist, when it negotiates with firm i, is the profit it would reap in an exclusive relationship with firm j.[24] Consequently, the Nash products write

$$NP_i^N(\hat{q}_j^N, T_i, T_j) = [\overline{\Pi}_i(\hat{q}_j^N, T_i, T_j) - \overline{\Pi}_m(T_j)]^\mu [\overline{\pi}_i(\hat{q}_j^N, T_i)]^{1-\mu}, \quad i \in \{1,2\}, i \neq j \tag{44}$$

By maximizing Nash products in (44) with respect to T_1 and T_2, substituting back the equilibrium quantities $\bar{q}_i^N(w_i, w_j) = \frac{2}{15}(3\alpha - 4w_i + w_j), i, j = 1, 2, i \neq j$ and finally solving for w_i and t_i leads to

$$T_i^N \equiv \{w_i^N, t_i^N\} = \left\{0, \frac{4\alpha^2\mu}{25}\right\}, \quad i \in \{1,2\}. \tag{45}$$

As expected, royalty rates are set to 0. Indeed, as shown previously in the literature, under Cournot competition and unobservable contracts, the equilibrium royalty should be equal to the marginal cost of the upstream monopolist. As a consequence, the fixed part of the contract is a fraction of the profits of downstream firms depending mainly on the bargaining power of the upstream monopolist.

Lemma 8. *In the case of a non-exclusive contract without production by firm U, the equilibrium contracts are T_i^N. Equilibrium prices and quantities are $p_i^N = q_i^N = \frac{2\alpha}{5}$ and profits of the upstream and the downstream firms are $\Pi^N = \frac{8\alpha^2\mu}{25}$ and $\pi_i^N = \frac{4\alpha^2(1-\mu)}{25}$, respectively. The consumer surplus is $CS^N = \frac{6\alpha^2}{25}$.*

From direct comparison of Π^N and Π^P, option N is dominated by option P for firm U.

B PaC: dominated options

B.1 Option EC: Exclusive contract and no production by firm U

This option is easily dealt with, because it coincides with option E above (see Appendix A.2) with the notable exception that, because of the presence of the clearinghouse, the outside options of the firms at the bargaining stage are no longer zero, but are dictated by the arbitrator. It is clear that given the exclusivity choice of firm U, the royalty rate chosen by the arbitrator is $w_1 = 0$, and the value of the sales of the -unique- product available is $\frac{\alpha^2}{4}$. This value is shared between firms U and 1, according to the arbitrator's preferences, which reap, off the equilibrium path, $\eta\frac{\alpha^2}{4}$ and $(1-\eta)\frac{\alpha^2}{4}$ respectively: these are the outside options

[24] Here we will assume that contracts are not contingent, so that the equilibrium contractual terms are the same along and off the equilibrium path.

of the firms at the negotiation stage. The negotiation between U and 1 is then set to the terms of contrat chosen by the arbitrator.

B.2 Option NC: Non-exclusive contract and no production by firm U

This option is easily dealt with, because it coincides with option N above (see Appendix A.3) except that the outside options of the firms at the bargaining stage are no longer zero, but are dictated by the arbitrator. As in the case with exclusivity (option EC), the negotiation between U and 1 is set to the terms of contrat chosen by the arbitrator. The royalty rate chosen by the arbitrator is $w_1 = 0$, and the value of the sales of the product 1 is then $\frac{4\alpha^2}{25}$. This value is shared between firms U and 1, according to the arbitrator's preferences, which reap, $\eta\frac{4\alpha^2}{25}$ and $(1-\eta)\frac{4\alpha^2}{25}$ respectively. As in the case without PaC, $w_2 = 0$ and the value of the sales of the product 2 is $\frac{4\alpha^2}{25}$. This value is shared according to the bargaining weights between firms U and 2, which reap, $\mu\frac{4\alpha^2}{25}$ and $(1-\mu)\frac{4\alpha^2}{25}$ respectively.

Lemma 9. *In the case of a non-exclusive contract without production by firm U, equilibrium prices and quantities are $p_i^{NC} = q_i^{NC} = \frac{2\alpha}{5}$ and profits of the upstream and the downstream firms are $\Pi^{NC} = \frac{4\alpha^2(\eta+\mu)}{25}$, $\pi_1^{NC} = \frac{4\alpha^2(1-\eta)}{25}$ and $\pi_2^{NC} = \frac{4\alpha^2(1-\mu)}{25}$, respectively. The consumer surplus is $CS^{NC} = \frac{6\alpha^2}{25}$.*

From direct comparison of Π^{NC} and Π^{NPC}, option NC is dominated by option NPC for firm U.