



Contents lists available at SciVerse ScienceDirect

Information Economics and Policy

journal homepage: www.elsevier.com/locate/iep

Patent pool formation: Timing matters

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ARTICLE INFO

Article history:

Received 6 August 2010

Received in revised form 4 July 2011

Accepted 15 July 2011

Available online xxxx

Keywords:

Patent

Patent pool

Hold-up

Hold-out

Standard

Double-marginalization

ABSTRACT

This paper addresses the problem of non-cooperative patent pool formation by owners of patents related to a standard. We develop a model in which competing manufacturers must license several patents to produce standard-compliant goods. Separate licensing creates a double-marginalization problem. Moreover manufacturers must sink a fixed cost to enter the product market, and thus face a hold-up problem if licensing takes place after their entry. In this setting, the formation of a pool fails when it takes place after entry. Instead, we show that allowing patent owners to commit *ex ante* on joining a pool is an effective way to trigger the emergence of a stable pool solving both the double-marginalization and hold-up problems. Therefore, patent owners should be encouraged to coordinate their licensing policies on a voluntary basis at early stages in the standard-setting process.

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1. Introduction

During the last two decades, the number of patented inventions incorporated in technology norms such as the DVD, MPEG and WCDMA standards has increased dramatically (Simcoe, 2005). Licensing of these patents to manufacturers of standard-compliant goods raises two well-known issues. First, patent owners tend to charge excessive royalties when they grant licenses separately. This double-marginalization lowers demand for standard-compliant products and also lowers profits for the patent owners themselves (Shapiro, 2001). The other issue concerns patent hold-up. When licensing conditions and schemes are set after manufacturers have incurred irreversible costs to adopt the standard, patent owners can charge royalties that are higher than the manufacturers expected, thereby creating a climate of defiance that may deter the adoption of standards in the long term (Farrell et al., 2007; Lemley and Shapiro, 2007).

Practical solutions to excessive royalties and the problem of patent hold-ups have are not completely effective.

Creating patent pools that license patents jointly is one solution for double-marginalization. Yet, patent pool formation often fails in practice. It is more profitable for a patent owner to keep its patents out and take advantage of the existence of the pool to raise its own royalties (US Department of Justice and Federal Trade Commission, 2007). To prevent the hold-up problem, standard setting organizations commonly require that owners make early commitments to license their patents under Reasonable and Non Discriminatory (RAND) terms. However these commitments remain vague and are difficult to enforce.¹

In contrast, we show here that binding licensing commitments are an effective way to mitigate both the hold-up and double-marginalization problems. We develop a simple model that captures both issues. Competing manufacturers of standard-compliant products license patents incorporated into the standard from k different owners. Since adopting a standard entails specific investments in the technology, we consider that manufacturers must sink

¹ Recent cases have shed light on their limited effectiveness. The two most frequently cited cases involve Rambus and Qualcomm, which were accused of hiding essential patents covering the RAM standard, and breaking a commitment to license 3G patents on Reasonable terms, respectively.

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a fixed cost to enter the market. If licensing takes place after entry, patent owners can hold-up captive manufacturers and charge them higher royalties. Due to double-marginalization, the royalties increase more if patent owners set their royalties separately. Eventually, both hold-up and double-marginalization reduce entry into the product market, which in turn raises the prices of standard-compliant products.

We use this setting to compare two patent pool scenarios, wherein the pool members evenly share the pool's licensing revenue. In a first benchmark scenario the pool is created after the manufacturers have sunk their fixed cost, as is usually the case. We refer to this as the *ex post* scenario. The second scenario corresponds to the *ex ante* formation of the pool. In this case, patent owners wishing to join a pool have to commit to a joint royalty before the entry of the manufacturers. Most importantly, we assume that both commitments to join the pool and to apply the announced royalty are binding.²

This scenario is inspired by an arrangement currently in use in the emerging mobile network technology known as Long Term Evolution (LTE). In 2008, some of the world's largest telecom companies, including Nokia, Ericsson, and Alcatel-Lucent, agreed to a licensing framework for their LTE patents in handsets. The companies have committed to keeping royalty levels on the essential LTE patents below 10% of the sale price.³ In contrast to former patent pools, this initiative took place at an early stage in LTE deployment; the early commitment was meant to boost the adoption of this new technology.

Our results provide theoretical support for a framework of early patent pooling. We show that *ex ante* commitment on future royalties that manufacturers will have to pay triggers the formation of a stable patent pool. This in turn induces more entry into the product market. Interestingly, this outcome is entirely driven by non-cooperative strategies, while patent pool formation is usually perceived as cooperative problem. In contrast, patent owners nearly always fail in creating a pool *ex post* if they cannot cooperate.

The formation of an *ex ante* pool is driven by two factors that are absent in the *ex post* scenario. First, the *ex ante* commitment confers a first mover advantage to the pool members. In some cases, they will use it as a Stackelberg advantage to charge even higher royalties than would occur in an *ex post* situation. However this behavior disappears as the size of the pool increases, and in equilibrium the pool always charges lower royalties per patent licensed. Indeed, the formation of the pool is chiefly driven by enhanced incentives to reduce royalties. Besides avoiding double-marginalization, patent owners can promote the entry of more manufacturers by committing *ex ante* to lower royalties. Royalty decreases are then compensated for by the entry of more licensees, which in turn reinforces the benefit of joining a pool. In other words, the

effectiveness of *ex ante* commitment in promoting patent pools lies in the full internalization of the effects of royalties on the product market.

This result is new to the literature on patent pools. It is well established that patent pools are welfare improving provided the pooled patents are complementary (Shapiro, 2001; Gilbert, 2004; Kim, 2004; Lerner and Tirole, 2004; Lerner et al., 2007). Some studies also show that patent pools may fail to emerge as a stable coalition (Aoki and Nagaoka, 2004; Brenner, 2009). Brenner (2009) addressed the issue of optimal patent pool formation when pools may be either pro- or anticompetitive, which depends on the degree of complementarity among patents. He established that combining exclusive pool membership with the obligation for pool members to offer individual licenses in parallel ensures that only welfare increasing pools emerge at equilibrium. His closed form specification of the demand for licenses, adapted from Lerner and Tirole (2004), accounts for imperfect complementarity, but it does not lend itself easily to analyzing the hold-up problem. As an alternative, we consider the simpler case of pure complementarity between patents and focus the analysis on investment and competition in the market for standard-compliant products.

One key feature of our model is that it captures the entry deterrence effect of patent hold-up, which is eventually detrimental to patent holders. In that respect our model can be related to Rey and Salant's (2009) analysis of the licensing of complementary patents related to a standard. Others have discussed the interpretation of the RAND licensing commitments as a means to solve the hold-up problem (Swanson and Baumol, 2005; Farrell et al., 2007; Lemley and Shapiro, 2007) with the goal of connecting the level of individual royalties with the value of each patent. Our analysis explores an alternative approach, whereby the object of *ex ante* commitments is the pricing of a package of essential⁴ patents, so as to address both the hold-up and double-marginalization issues.

This paper is organized into four sections. We introduce our basic settings in Section 2. The *ex post* and *ex ante* patent pool scenarios are analyzed in Sections 3 and 4, respectively. We conclude and discuss policy implications in Section 5.

2. Market for standard-compliant products

We consider the licensing of a technology standard to n firms competing à la Cournot in the market for standard-compliant products. The standard embodies a set \mathcal{K} of k patents,⁵ each of which belongs to a different owner. For the sake of simplicity we assume no vertical integration: patent owners are pure R&D firms and do not manufacture standard-compliant products themselves. The manufacturers pay a per unit royalty R for the bundle of the k patents. The inverse demand function to manufacturer i can be written as

² Currently, RAND licensing commitments are considered to be weakly binding because they are vague. The commitment we propose is not subject to that limitation since it makes explicit the cumulative royalty that will be charged for a package of patents.

³ Reuter, "Nokia, Ericsson and others in mobile tech agreement" Mon April 14, 2008.

⁴ Patents are "essential" if each of them is necessary to implement the standard, and none of them has a substitute.

⁵ We assume that these patents are "essential" (cf. note 5 supra). Hence all of them must be licensed in by any manufacturer of standard-compliant products.

$$P = x - \sum_{j=1}^n q_j$$

where $x > 0$ is the demand intercept and q_j denotes the production of manufacturer $j = 1, \dots, n$. Without a loss of generality, the unit production costs of manufacturers is assumed to be zero so that manufacturers pay the per unit royalty R for using the technology standard. The program of a manufacturer writes:

$$\max_{q_i} q_i \left(x - q_i - \sum_{j \neq i} q_j - R \right)$$

At symmetric equilibrium, the individual production q_M and profit π_M of a manufacturer are respectively:

$$q_M(R, n) = \frac{x - R}{n + 1} \tag{1}$$

$$\pi_M(R, n) = q_M^2 \tag{2}$$

We assume there is an irreversible fixed cost E to enter the downstream market, which we normalize to $E = 1$. At free entry equilibrium, firms enter the market until $\pi_M(R, n) = q_M(R, n) = 1$. Although n should be an integer, we can treat it as a continuous variable for the sake of simplicity without significantly altering our results. The number of manufacturers is thus given by

$$n = \arg \max \{0, x - R - 1\} \tag{3}$$

The higher the cumulative royalty R , the fewer are the number of manufacturers who can enter the market for standard-compliant products. If $R > x - 1$, the cost of licensing may deter entry entirely. However, it is unlikely that firms would make an R&D investment in a standard if they expect that no standard-compliant good will be produced. To prevent this inconsistency, we will introduce an assumption on x and k at the end of Section 3.

3. Scenario 1: Ex post patent pool

We first study a benchmark scenario wherein licensing takes place after manufacturers have entered the market. Consequently, the number n of licensees is known when patent owners set their royalties. Our purpose is to analyze whether some patent owners will then agree to form a patent pool under such a circumstance. The timing of the game is as follows:

- (1) manufacturers enter the market,
- (2) patent owners decide whether to join a patent pool, and
- (3) the patent pool and the independent licensors set the royalties.

We solve this backwards. We start with stages 3 then 2 taking n as given, before analyzing the manufacturers' entry decision.

3.1. Stage 3: Licensing

Let us assume that a set \mathcal{L} of l patent owners has joined the patent pool. The pool sets a joint royalty $r_{\mathcal{L}}$, and its

members share its licensing revenue equally.⁶ The remaining set $\mathcal{I} = \mathcal{K} \setminus \mathcal{L}$ consists of $k - l$ patent owners that fix their individual royalties $r_{\mathcal{I}}$ independently. Note that we have $l \geq 1$, where $l = 1$ indicates that all patent owners license separately. For the sake of simplicity, we will treat l as a continuous variable on interval $[1, k]$ in the equations.

Let $\pi_i = nq_M r_i$ denote the profit of licensor i , be it the pool or an independent licensor, when he sets a royalty r_i . Using (1) and noting \bar{R} the cumulative royalty charged by the other licensors, we can write:

$$\pi_i(r_i) = \frac{n}{n + 1} r_i (x - r_i - \bar{R}) \tag{4}$$

Maximizing π_i with respect to r_i yields the following royalty at symmetric equilibrium:

$$r_{\mathcal{L}}(l) = r_{\mathcal{I}}(l) = \frac{x}{k - l + 2}, \quad l = 1, k \tag{5}$$

The patent pool behaves as another independent licensor; it charges the same royalty and makes the same profit. The cumulative royalty paid by each manufacturer is thus:

$$R(l) = r_{\mathcal{L}}(l) + (k - l)r_{\mathcal{I}}(l) = kr_{\mathcal{I}}(l) \tag{6}$$

Using (5) and (6) in (4) we can calculate the respective profits of the pool (noted $\Pi_{\mathcal{L}}$) and of an individual licensor ($\pi_{\mathcal{I}}$):

$$\pi_{\mathcal{I}}(l) = \Pi_{\mathcal{L}}(l) = r_{\mathcal{I}}(l)Q(R(l)) = \frac{n}{n + 1} \left(\frac{x}{k - l + 2} \right)^2 \tag{7}$$

This equation captures the double-marginalization problem. $\pi_{\mathcal{I}}$ decreases with the number $(k - l)$ of independent licensors. Conversely, it is maximized when all the patent owners have joined the patent pool (e.g., when $l = k$). Since the pool members share the profit made by the pool equally, their individual profit $\pi_{\mathcal{L}}$ is thus:

$$\pi_{\mathcal{L}}(l) = \frac{\Pi_{\mathcal{L}}(l)}{l} = \frac{1}{l} \frac{n}{n + 1} \left(\frac{x}{k - l + 2} \right)^2 \tag{8}$$

Since the total profit of the pool equals the profit of an independent licensor, a member of a pool of size l gets only a fraction $1/l$ of an independent licensor's profit. As the size of the pool increases, the benefits of reducing double-marginalization and the need to share licensing revenues are in opposition for the pool members, as represented in Fig. 1.

While independent licensors always benefit from a larger pool, the effect of the pool's size on its members' profit is more ambiguous. The benefit of reducing double-marginalization dominates only if the pool is large enough ($l > (k + 2)/3$). A pool that includes a grand coalition of all patent owners ($l = k$) generates more individual profits than in the absence of a patent pool ($l = 1$). However, the effect of profit dilution prevails when the pool is small and there are many independent licensors ($l < (k + 2)/3$).

⁶ This assumption is consistent with the way patent pools typically allocate their licensing revenue. Each member's share of the total royalty revenue is proportionate to his share of the patents out of all the patents licensed by the pool.

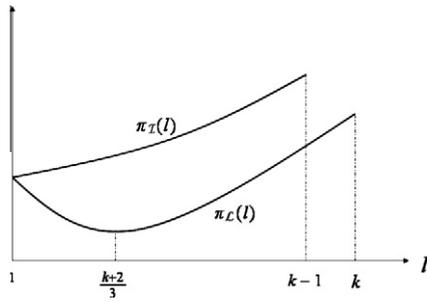


Fig. 1. Licensing profits: *Ex post* patent pool.

3.2. Stage 2: Patent pool formation

We can now analyze whether a pool will emerge at stage 2. To do so, we check whether a pool of l patent owners can be a pure strategy subgame-perfect Nash equilibrium. A pool of size l is stable if an independent licensor prefers to stay out of the pool (e.g. if $\pi_T(l) < \pi_C(l+1)$) while, conversely, a member of the coalition prefers to stay in ($\pi_T(l-1) < \pi_C(l)$).

Checking stability for all $1 \leq l \leq k$ is straight forward since profits in (7) and (8) actually replicate the payoffs of a cartel of l firms in a k -firms Cournot oligopoly with homogenous products (Bloch, 2002). This coalition formation problem has a well-known solution:

Proposition 1. (Bloch, 2002) *If $k = 2$, there is a unique Nash equilibrium $l^* = 2$ where the patent owners form a patent pool. If $k > 2$, there is a unique Nash equilibrium $l^* = 1$ where all patent owners license separately.*

A patent pool based on a coalition can only be a Nash equilibrium if there are two patent owners. Otherwise, it is always subject to strategic instability. Stability when $k = 2$ is due to the absence of the possibility of free riding on the effort of the other to decrease royalties. When $k \geq 3$, it is always profitable for at least one patentee to keep his patent out instead of joining a pool of any size.

3.3. Stage 1: Entry of manufacturers

Having solved stages 2 (patent pool formation) and 3 (licensing game), we now analyze the entry decisions of manufacturers. The number of manufacturers at free entry equilibrium, as given in (3), depends on the expected cumulative royalty R . We must consider two cases: $k = 2$ and $k > 2$.

If $k = 2$, the patent owners will form a pool and manufacturers must only buy one license and pay a royalty $R = x/2$. Using (3), we can deduce the number of entrants for an entry cost for $E = 1$:

$$n = \begin{cases} \frac{x-2}{2} & \text{if } x > 2 \\ 0 & \text{otherwise} \end{cases}$$

Observe that $x \in (1, 2]$ implies complete entry deterrence. Although, according to Eq. (3), there exists some $R \geq 0$ such that $n \geq 1$ would be possible in this interval. This failure is not due to double-marginalization since there is only

one license. It is due to the hold-up issue, as captured in our model. The patent pool fails to internalize the effect of the royalty on entry, and thus ends up charging too high a royalty.

This problem is amplified when $k > 2$. In this case all patents are licensed separately and the cumulative royalty is $R(0) = kr_T(0) > r_C(k)$. Double-marginalization further reduces the gross profit π_M of the manufacturers, thereby making it more difficult for them to recoup the entry cost E . Condition (3) gives:

$$n = \begin{cases} \frac{x-(k+1)}{k+1} & \text{if } x > k+1 \\ 0 & \text{otherwise} \end{cases}$$

The number of entrants is decreases in k when $x > k+1$, while entry is entirely deterred otherwise. These results highlight a fundamental drawback of the usual timing of standard licensing. Once manufacturers have sunk some fixed costs, they are locked into the market for standard-compliant products. This creates a hold-up pattern, which is eventually amplified by double-marginalization, whereby patent owners charge high royalties that then deter entry into the market.

Although complete entry deterrence is possible in our model – and useful to highlight the hold-up problem – this extreme outcome is very unlikely if we take into account the R&D firms’ investment strategies. These firms will not make any R&D investment into a standard if they expect that no standard-compliant good would be produce. To prevent this inconsistency, we make the following hypothesis:

Assumption 1. $x > k+1$

This condition imposes a positive correlation between the number of patents, k , and the value of the standard, as measured by x . It ensures that $n > 0$ when the patent holders grant separate licenses ($k > 2$), which in turn guarantees that entry always take place when a pool is formed ($k = 2$).

4. Scenario 2: *Ex ante* patent pool

Having highlighted the inefficiency induced by *ex post* licensing, now we explore an alternative licensing scenario wherein patent owners may form a patent pool before the end of the standard-setting process. We assume that one or more patent owners can choose to delegate the licensing of their patents to a third party. In turn, this third party will announce a (profit maximizing) joint royalty before manufacturers enter the market. We assume that these commitments are binding and are contracted with the Standard Setting Organization and enforceable. In contrast, patent holders who decide not to join the *ex ante* pool have no means to make a credible commitment on their royalty before manufacturers have entered the market, and they do not have the possibility to form a pool *ex post*.⁷ The timing of the game is now the following:

⁷ This assumption is not required to obtain our results. Allowing *ex post* pools in the *ex ante* scenario would indeed only result in the existence of a two-members *ex post* pool next to the *ex ante* one in a small number of subcases. We rule out this possibility for the sake of clarity, as it would substantially complicate the paper without providing key insights.

- (1) patent owners decide whether to join a patent pool,
- (2) the patent pool commits to a joint royalty,
- (3) manufacturers enter the market, and
- (4) independent licensors set the royalties.

As before, we solve this game backwards, starting with the licensing strategies of independent licensors at stage 4.

4.1. Stage 4: Independent licensors

We assume now that a set \mathcal{H} of h patent owners have joined the pool and fixed a joint royalty $r_{\mathcal{H}}$ before manufacturers invest E . The remaining set $\mathcal{J} = \mathcal{K} \setminus \mathcal{H}$ of $k - h$ patent owners fix their individual royalties $r_{\mathcal{J}}$ independently after the manufacturers have entered the market. Note that we may now have $h = 0$. Indeed $h = 1$ implies not only that all k patent owners grant separate licenses, but also that one of these patent owners has made an *ex ante* commitment. As in the previous section, we treat h as a continuous variable on $[0, k]$ to solve the equations.

We consider the profit maximization program of an independent licensor given $r_{\mathcal{H}} < x$. Each independent licensor $j \in \mathcal{J}$ perceives the number of manufacturers as an exogenous variable. Maximizing the profit of each independent licensor with respect to r_j and solving for the symmetric equilibrium among all independent licensors given the pool's royalty $r_{\mathcal{H}}$, yields the following royalty per licensor:

$$r_{\mathcal{J}}(h, r_{\mathcal{H}}) = \begin{cases} \frac{x-r_{\mathcal{H}}}{k-h+1} & \text{if } h \in \{1, \dots, k-1\} \\ \frac{x}{k+1} & \text{if } h = 0 \end{cases} \quad (9)$$

Note that $h = 0$ implies that the patent pool is empty, so all patent owners set their royalties *ex post* and independently. We obtain the same fully decentralized outcome as in the previous Section. The pool is not empty if $h \geq 1$. In that case an increase in the royalty of the pool drives a decrease in the royalties of independent licensors.

4.2. Stage 3: Manufacturers entry

Using (3), we can derive from $r_{\mathcal{H}}$ and $r_{\mathcal{J}}(h, r_{\mathcal{H}})$ the number of manufacturers that enter the market. The result depends on whether a patent pool has been formed *ex ante* or not.

$$\hat{n} = \begin{cases} \arg \max \left\{ 0, \frac{x}{k+2} - 1 \right\} & \text{if } h = 0 \\ \arg \max \left\{ 0, \frac{x-r_{\mathcal{H}}}{k+1-h} - 1 \right\} & \text{if } h > 0 \end{cases} \quad (10)$$

The case $h = 0$ simply reproduces the result of the *ex post* scenario when no patent pool is formed. The effect of the *ex ante* pool can be observed in the second case ($h > 0$). The number of entrants increases with the size h of the pool as double-marginalization diminishes while a higher royalty $r_{\mathcal{H}}$ reduces entry, and may block entry entirely if $r_{\mathcal{H}} > x - (k + 1) + h$. However, we will see below that this is never the case under Assumption 1.

4.3. Stage 2: Joint royalty setting

We now consider the problem of the patent pool's royalty setting decision. Since the patent pool moves first, its

members can anticipate how its royalty $r_{\mathcal{H}}$ will affect the $(k - h)$ independent licensors' royalties and the manufacturers' entry decisions.

Observe that under Assumption 1 we necessarily have $x - (k + 1) > 0$, so that an *ex ante* pool of size $h > 1$ can always set a royalty $0 < r_{\mathcal{H}} < x - (k + 1) + h$ that triggers the entry of manufacturers. Since free entry implies that each manufacturer produces $q = 1$ (Section 2), the patent pool sets a royalty r so as to maximize its profit $\pi(r)q = \pi(r)$. This programme can be written as follows:

$$\max_{r \in [0, x - (k+1) + h]} r \left(\frac{x - r}{k + 1 - h} - 1 \right)$$

with a unique interior solution:

$$r_{\mathcal{H}}(h) = \frac{x - (k + 1 - h)}{2} \quad (11)$$

The royalty set by the pool, and the resulting number of manufacturers, decrease with the number $k - h$ of independent licensors and, conversely, increase with the size h of the pool. This is consistent with the *ex post* pool scenario. However, the *ex post* and *ex ante* patent pool scenarios differ on two important points.

First, internalizing the manufacturers' entry decisions decreases the pool's royalty. By maximizing $\pi(r)q$ instead of $nq(r)r$, the pool has indeed an incentive to promote entry by reducing r . This is evident when comparing the royalties set by the grand patent pool ($h = k$) in the *ex post* and *ex ante* scenario. We then have:

$$r_{\mathcal{L}}(k) - r_{\mathcal{H}}(k) = \frac{1}{2} > 0$$

Lemma 2 (*Entry promotion effect*). *The grand patent pool sets a lower royalty if it is formed ex ante.*

Moreover, in the *ex ante* scenario, the pool enjoys a first mover advantage vis-à-vis the independent licensors. The royalty setting game has a Stackelberg pattern, whereby the pool can anticipate the independent licensors' reaction while moving first. We can see from (9) that the pool can impose a higher royalty $r_{\mathcal{H}}$ and oblige independent licensors to reduce $r_{\mathcal{J}}$. As stated in Lemma 3, the pool will choose to do so only in some cases.

Lemma 3. [Stackelberg effect] *Assume that $k - 1$ patent owners grant separate licenses ex post. Consider now the royalty set by the remaining patent owner (i) if he also grants a license ex post: $r_{\mathcal{J}}(0)$, or (ii) if he chooses to commit ex ante: $r_{\mathcal{H}}(1)$. Then we have*

- $r_{\mathcal{H}}(1) \leq r_{\mathcal{J}}(0)$ if $x \in ((k + 1), \frac{k}{k-1}(k + 1)]$,
- $r_{\mathcal{H}}(1) > r_{\mathcal{J}}(0)$ if $x \in (\frac{k}{k-1}(k + 1), \infty]$.

Proof. Obvious and thus omitted. \square

When the patent pool is initially empty, the first patent owner that makes an early commitment increases his royalty if $x > k(k + 1)/(k - 1)$. This denotes a Stackelberg advantage, whereby the first mover is able to charge a higher price, to the detriment of the other licensors.

However, this results only holds if the market is sufficiently profitable (e.g., if x is large) and/or the number k of licensors is small. In contrast, if $x \in ((k + 1), \frac{k}{k-1}(k + 1)]$, the entry deterrence effect created by double-marginalization is too acute and it is more profitable for the single licensor moving *ex ante* to charge a lower royalty in order to promote entry.

4.4. Stage 1: Patent pool formation

We now consider the problem of patent pool formation. Using (9)–(11), we can reformulate the profit π_J and π_H of an independent licensor and the profit of a member of the patent pool. These profits can be expressed as follows:

$$\pi_J(h) = \left(\frac{x}{k+1}\right)^2 - \frac{x}{k+1} \quad \text{if } h = 0 \tag{12}$$

$$\pi_J(h) = \frac{x^2 - (k+1-h)^2}{4(k+1-h)^2} \quad \text{if } h \in [1, k-1] \tag{13}$$

$$\pi_H(h) = \frac{1}{h} \frac{[x - (k+1-h)]^2}{4(k+1-h)} \quad \text{if } h \in [1, k] \tag{14}$$

Comparing these profits reveals two possible cases,⁸ as illustrated in Figs. 2 and 3. When the number of patent owners is not too high (Fig. 2) a single patent owner choosing to commit *ex ante* can benefit from a Stackelberg advantage. When $h = 1$, the first mover charges a higher royalty, thereby obliging the other licensors to charge lower royalties at stage 4. As a result the first mover's profit is higher and the other licensors' profits lower for $h = 1$ compared to $h = 0$.

As more patent owners decide to commit *ex ante*, the pool mitigates the double-marginalization problem and facilitates the entry of manufacturers. Consequently, the profit of the remaining patent owners increase with the size of the pool. As in the *ex post* pool, the profit of each pool member decreases as h increases beyond 1 due to the dilution of the pool's revenue among a larger number of members. This is true up to a threshold \hat{h} , where the profit of a pool member reaches a minimum. The profit of all licensors, be they within or out of the pool, are then equal.⁹ Beyond that threshold (e.g., for $h > \hat{h}$), the benefits of reducing double-marginalization and entry promotion dominate the loss due to profit dilution, so that the profit of the pool members starts to increase with the size of the pool.

Fig. 3 illustrates when the number of patent owners is high. Here the first pool member does not benefit from a first mover advantage and directly reduces his royalty so as to promote entry. This is always profitable, but even more so for the other patent owners who do not take part in the royalty mitigation effort. In this context, any increase in the pool's size will benefit the pool members, since the gain of entry promotion through reduced

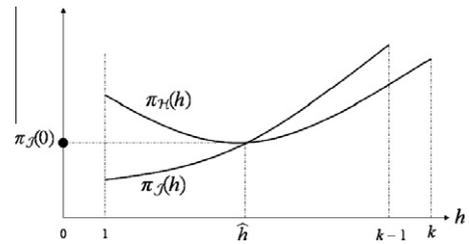


Fig. 2. Licensing profits when $x \in (\frac{k}{k-1}(k + 1), \infty)$.

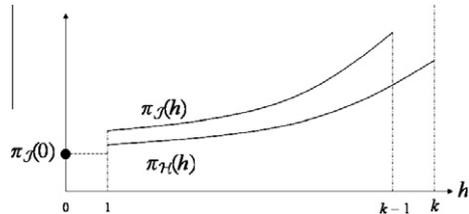


Fig. 3. Licensing profits when $x \in ((k - 1), \frac{k}{k-1}(k + 1))$.

double-marginalization is always stronger than the loss due to profit dilution. Of course, the existence of a large pool also benefits the remaining independent licensors, who make a greater profit than the pool members.

Finally in both Figs. 2 and 3 a pool of size k generates higher individual profits than purely decentralized licensing. However, it is uncertain whether a member of the grand patent pool will always have an incentive to drop out and license separately. We need to establish whether a stable patent pool of size $h > 0$ can emerge as a Nash equilibrium. We can establish the following result.

Proposition 4. Fully decentralized licensing is never a Nash equilibrium in pure strategies when *ex ante* pools are possible. If $k \in \{2, 3\}$ all firms form an *ex ante* pool in equilibrium. If $k \geq 4$, there always exists a Nash equilibrium involving the creation of a pool of size $h^* \in]\max\{1, \hat{h}\}, k[$.

Proof. See Appendix A. □

Corollary 5. The equilibrium h^* is welfare improving with respect to $h = 0$. Hence early commitment is welfare improving as compared with the *ex post* scenario for any $k \geq 2$.

The Proposition establishes that *ex ante* commitments always induce the creation of a stable patent pool if entry is not foreclosed in absence of a pool. Interestingly, the pool may not include all the patent owners. The grand patent pool actually emerges in equilibrium only if $k \in \{2, 3\}$. Otherwise some patent owners will find it more profitable to stay out of the pool. However, the size of the pool will nevertheless stabilize at a level $h^* > \hat{h}$.

The *ex ante* pool clearly improves welfare with respect to purely decentralized licensing (e.g., $h = 0$). The pool members and independent licensors make larger profits. On the other hand, $h^* > \hat{h}$ implies lower cumulative royalties, even though the Stackelberg effect may initially

⁸ See Appendix A for detailed calculations.

⁹ At \hat{h} the royalty share of a member of the pool ($r_H(\hat{h})/\hat{h}$) becomes equal to the royalty charged by an independent licensor ($r_J(\hat{h}, r_H(\hat{h}))$). This in turn implies that both are equal to the royalty charged in absence of a pool ($r_J(0, 0)$). Consequently the profit of a patent owner when $h = \hat{h}$ is equal to its profit when $h = 0$.

prevail when $h < \hat{h}$. As a result, more manufacturers can enter the product market, and they charge lower prices to consumers. Clearly, the key driver of the equilibrium is the incentive to lower royalties in order to promote entry. The Stackelberg effect plays an interim role when $h < \hat{h}$, but it is not a necessary condition since the pool also emerges when $h > \hat{h}$.

The formation of a patent pool is the result of purely individual, non-cooperative strategies. The creation of an *ex ante* patent pool is not a problem of cooperation in this case.

5. Conclusion

This paper considers the non-cooperative formation of a patent pool by owners of essential patents incorporated in a standard. In contrast with previous analyses, we addressed this question with a setting that takes into account both double-marginalization and hold-up, and their entry deterrence effect in the product market.

This setting captures the cooperation issue raised by the formation of patent pools. In particular, it shows in particular that pools cannot emerge as a non-cooperative equilibrium when their formation takes place after manufacturers have sunk the cost of entry in the market for standard-compliant products.

We explored an alternative scenario in which the pool is formed at an earlier stage in the standard setting process, before the entry of manufacturers. In contrast with the *ex post* pool, this arrangement makes it possible for the pool members to mitigate the hold-up problem and thus foster entry into the product market. We have shown that this type of arrangement always induces the formation of an *ex ante* pool, either including all patent owners or a subset of them. This outcome is driven by non-cooperative decisions of patents owners, and therefore overcomes the major drawback of *ex post* patent pools. Both consumers and patent owners benefit from the *ex ante* pool (the profit of manufacturers being always driven to zero by free entry), which is therefore welfare improving.

Our analysis echoes the current policy debate on *ex ante* licensing commitments in standard-setting organizations.¹⁰ Our findings suggest that allowing that pools be formed *ex ante* is sufficient to trigger the formation of efficient pools on a voluntary basis. This result chiefly depends on the pool members' capability of credibly committing on licensing terms at an early stage of the standard setting process, before users are locked in the standard. This implies that standard-setting organizations and antitrust authorities do not need to regulate royalties directly. Rather, they should be open to early licensing arrangements and make sure that such commitments can be enforced effectively.

By assuming pure complementarity among patents, we did not consider the possibility that early pools could be anticompetitive. Since the benefit of such pools is to foster

standards adoption by committing to lower royalties, we expect that this type of arrangement would not be attractive for owners of substitutable patents. However, this question deserves further analysis, and relaxing the assumption of pure complementarity would thus be an interesting extension of this paper.

Acknowledgments

The authors thank the Editor, Associate Editor and referee for helpful comments and suggestions.

Appendix A

A.1. Proof of Proposition 4

We proceed in four steps. We study first the shape of the individual profit of pool members and independent licensors in function of the size of the pool. We show then on what conditions a pool of size $h = k$ can be an equilibrium. We show as third and fourth steps that when the grand patent pool is not an equilibrium, there always exists an equilibrium pool of size $h > \max\{\hat{h}, 1\}$.

Step 1: Effect of the pool on individual profits of patent owners

It is obvious that $\pi_{\mathcal{J}}$ is increasing in h on $[1, k]$. Noting $\Pi_{\mathcal{H}} \equiv h\pi_{\mathcal{H}}$, we can moreover check that:

$$\frac{\partial \Pi_{\mathcal{H}}}{\partial h} = \frac{x^2 - (k - h + 1)^2}{4(k - h + 1)^2} = \pi_{\mathcal{J}} > 0 \text{ when } h \in [1, k]$$

and in turn:

$$\frac{\partial \pi_{\mathcal{H}}}{\partial h} = \frac{\partial (\Pi_{\mathcal{H}}/h)}{\partial h} = \frac{1}{h^2} \left[h \frac{\partial \Pi_{\mathcal{H}}}{\partial h} - \Pi_{\mathcal{H}} \right] < 0$$

\Leftrightarrow

$$\pi_{\mathcal{J}} < \pi_{\mathcal{H}}$$

The derivative of $\pi_{\mathcal{H}}$ with respect to h writes as follows:

$$\frac{\partial \pi_{\mathcal{H}}}{\partial h} = \frac{[x - (k - h + 1)](2hx - (k + 1)[x - (k - h + 1)])}{4h(k - h + 1)^2}$$

so that the sign of $\frac{\partial \pi_{\mathcal{H}}}{\partial h}$ depends on:

$$2hx - (k + 1)[x - (k - h + 1)]$$

We have:

$$2hx - (k + 1)(x - (k - h + 1)) < 0$$

\Leftrightarrow

$$h < (k + 1) \frac{x - (k + 1)}{2x - (k + 1)} \equiv \hat{h}$$

We can check easily that $\hat{h} > 0$ under Assumption 1. We can check as easily that $\pi_{\mathcal{H}}(k) < \pi_{\mathcal{J}}(k)$, so that $\pi'_{\mathcal{H}}(k) > 0$. When $h = 1$, we have

$$\pi_{\mathcal{H}}(1) > \pi_{\mathcal{J}}(1)$$

\Leftrightarrow

$$x > \frac{k}{k - 1}(k + 1)$$

¹⁰ See for instance the Conference on "Tensions between Intellectual Property Rights and the ICT standardisation process: reasons and remedies" organized by the European Commission on 22 November 2010 (http://ec.europa.eu/enterprise/sectors/ict/standards/extended/ict-ipr-conference_en.htm).

Hence $\pi_{\mathcal{H}}(h)$ is strictly increasing on $[1, k]$ when $x \leq \frac{k}{k-1}(k+1)$, and inverse-U-shaped when $x > \frac{k}{k-1}(k+1)$.

Finally simple calculation shows that

$$r_{\mathcal{J}}(\hat{h}) = r_{\mathcal{J}}(0) = \frac{x}{k+1}$$

Since $\pi_{\mathcal{H}}(\hat{h}) = \pi_{\mathcal{J}}(\hat{h})$, we can moreover conclude that $\frac{r_{\mathcal{H}}(\hat{h})}{\hat{h}} = r_{\mathcal{J}}(\hat{h})$, such that

$$(k - \hat{h})r_{\mathcal{J}}(\hat{h}) + r_{\mathcal{H}}(\hat{h}) = kr_{\mathcal{J}}(0)$$

It follows that the licensors face the same demand at $h = \hat{h}$ than at $h = 0$, and that $\pi_{\mathcal{H}}(\hat{h}) = \pi_{\mathcal{J}}(\hat{h}) = \pi_{\mathcal{J}}(0)$.

These findings can be summarized as follows:

- The profit $\pi_{\mathcal{J}}$ of an independent licensor is increasing in h on $[1, k-1]$.
- If $x \in (\frac{k}{k-1}(k+1), \infty)$, the profit $\pi_{\mathcal{H}}$ of a pool member is inverse-U-shaped in h on $[1, k]$. It reaches a minimum in $\hat{h} = (k+1) \frac{x-(k+1)}{2x-(k+1)}$. We have then:
 - $\pi_{\mathcal{H}}(1) > \pi_{\mathcal{J}}(0) > \pi_{\mathcal{J}}(1)$,
 - $\pi_{\mathcal{H}}(h) > \pi_{\mathcal{J}}(h)$ if $1 < h < \hat{h}$,
 - $\pi_{\mathcal{H}}(\hat{h}) = \pi_{\mathcal{J}}(\hat{h}) = \pi_{\mathcal{J}}(0)$,
 - $\pi_{\mathcal{H}}(h) < \pi_{\mathcal{J}}(h)$ if $\hat{h} < h$.
- If $x \in ((k+1), \frac{k}{k-1}(k+1)]$, the profit $\pi_{\mathcal{H}}$ of a pool member is increasing in h on $[1, k]$. We have then:
 - $\pi_{\mathcal{J}}(1) > \pi_{\mathcal{H}}(1) > \pi_{\mathcal{J}}(0)$,
 - $\pi_{\mathcal{H}}(h) > \pi_{\mathcal{J}}(h)$ for all $1 < h < k$.

A first direct implication is that $h = 0$ is not an equilibrium. Indeed we always have $\pi_{\mathcal{H}}(1) > \pi_{\mathcal{J}}(0)$, so that in absence of a pool one patent holder will always decide to commit *ex ante*.

Step 2: Stability of the grand patent pool ($h^* = k$)

We study now on what conditions an *ex ante* pool including all patent owners ($h = k$) can be an equilibrium. We have:

$$\pi_{\mathcal{H}}(k) = \frac{(x-1)^2}{4k}$$

$$\pi_{\mathcal{J}}(k-1) = \frac{x^2-4}{16}$$

When $h = k$, the incentive for one member to drop out thus writes:

$$\pi_{\mathcal{J}}(k-1) - \pi_{\mathcal{H}}(k) = \frac{1}{16} \left\{ (x-2)(x+2) - \frac{4(x-1)^2}{k} \right\}$$

Hence the grand patent pool is stable if

$$\pi_{\mathcal{J}}(k-1) - \pi_{\mathcal{H}}(k) \leq 0 \iff (x-2)(x+2) < \frac{4(x-1)^2}{k}$$

Recall that we have set $x > 2$. The condition thus holds for

$$k \leq \bar{k} \equiv \frac{4(x-1)^2}{(x-2)(x+2)} \tag{15}$$

It can be checked that \bar{k} is first decreasing from ∞ to 3 on $(2, 4]$, and then increasing from 3 to 4 on $[4, \infty)$. Hence:

- When $k = 2$ and $k = 3$, we necessarily have $k \leq \bar{k}$ since $\bar{k} \geq 3$. The grand pool is thus stable.
- When $k \geq 4$ we have $x \geq k+1 > 4$ (from Assumption 1) and thus $\bar{k} < 4$. Hence $k > \bar{k}$ and the grand pool is not stable.

Step 3: Existence of an intermediate patent pool ($h^* < k$) when $\hat{h} > 1$.

We consider now the case where $x \in [\frac{k}{k-1}(k+1), \infty)$, so that $\hat{h} > 1$.

Based on the previous results, we will show first that independent licensors have a positive incentive to join any pool of size $1 \leq h \leq \hat{h}$.

We know by definition of \hat{h} that:

$$\pi_{\mathcal{H}}(\hat{h}) = \pi_{\mathcal{J}}(\hat{h})$$

Since $\pi_{\mathcal{J}}$ is increasing in h , we also have $\pi_{\mathcal{J}}(\hat{h}-1) < \pi_{\mathcal{J}}(\hat{h})$. Hence:

$$\pi_{\mathcal{H}}(\hat{h}) > \pi_{\mathcal{J}}(\hat{h}-1)$$

So that we can expect one more independent licensor to join a pool of size $(\hat{h}-1)$. Since $\pi_{\mathcal{H}}$ and $\pi_{\mathcal{J}}$ are respectively decreasing and increasing on $[1, \hat{h}]$, we more generally have:

$$\pi_{\mathcal{H}}(\hat{h}-a) > \pi_{\mathcal{J}}(\hat{h}-1-a)$$

for any $a \in [0, \hat{h}-2]$. In other terms, more independent licensors have an incentive to join any *ex ante* pool of size $1 \leq h < \hat{h}$.

Finally $\pi_{\mathcal{H}}$ is increasing in h when $h > \hat{h}$. Since $\pi_{\mathcal{H}}(\hat{h}) = \pi_{\mathcal{J}}(\hat{h})$, we have thus:

$$\pi_{\mathcal{H}}(\hat{h}+1) > \pi_{\mathcal{J}}(\hat{h})$$

Hence a pool of size $h \leq \hat{h}$ cannot be an equilibrium, and any equilibrium would imply a size $h^* > \hat{h}$.

We now show that when the grand patent pool is not an equilibrium, there always exists an equilibrium with a stable patent pool of intermediate size.

Assume for this that condition (15) is not met. We have thus $\pi_{\mathcal{J}}(k-1) > \pi_{\mathcal{H}}(k)$.

Suppose now that $\hat{h} \geq 1$. Then we know that

$$\pi_{\mathcal{J}}(\hat{h}) < \pi_{\mathcal{H}}(\hat{h}+1)$$

Since $\pi_{\mathcal{J}}(h)$ and $\pi_{\mathcal{H}}(h+1)$ are continuous on $[\hat{h}, k-1]$, it follows that they cross at least once. Hence there is at least one equilibrium with a patent pool of size $h^* \in (\hat{h}, k-1)$.

Step 4: Existence of an intermediate patent pool ($h^* < k$) when $\hat{h} < 1$.

We finally consider the case where $x \in [k+1, \frac{k}{k-1}(k+1)]$, so that $\hat{h} < 1$. We already know that in this case $\pi_{\mathcal{J}}(0) < \pi_{\mathcal{H}}(1)$, and we can show in turn that $\pi_{\mathcal{J}}(1) < \pi_{\mathcal{H}}(2)$.

Indeed we have:

$$\pi_{\mathcal{J}}(h) \equiv \frac{x^2 - (k-h+1)^2}{4(k-h+1)^2}$$

$$\pi_{\mathcal{H}}(h+1) \equiv \frac{(x-k+h)^2}{4(h+1)(k-h)}$$

Hence the incentive to join the pool when $h = 1$ is:

$$\pi_{\mathcal{H}}(2) - \pi_{\mathcal{J}}(1) = \frac{(x - k + 1)^2}{8(k - 1)} - \frac{x^2 - k^2}{4k^2}$$

and

$$\pi_{\mathcal{H}}(2) - \pi_{\mathcal{J}}(1) > 0$$

\iff

$$(k^2 - 2k + 2)x^2 - 2k^2(k - 1)x + k^2(k - 1)(k + 1) > 0 \quad (16)$$

It can be checked easily that the polynomial on the left hand side has no root for all x in \mathbb{R} . Indeed the determinant of this polynomial is:

$$\Delta = -8k^2(k - 1) < 0$$

Since this result also holds for $\hat{h} > 1$, and since $\pi_{\mathcal{H}}(2) - \pi_{\mathcal{J}}(1) > 0$ when $\hat{h} > 1$, it follows that inequality (16) is also true when $\hat{h} < 1$.

From $\pi_{\mathcal{H}}(2) - \pi_{\mathcal{J}}(1) > 0$ and $\pi_{\mathcal{J}}(k - 1) > \pi_{\mathcal{H}}(k)$ when $k > 3$, and by continuity of $\pi_{\mathcal{J}}(h)$ and $\pi_{\mathcal{H}}(h + 1)$ on $[1, k - 1]$, we can conclude that there always exists $h^* \in]1, k[$ such that $\pi_{\mathcal{H}}(h^* + 1) = \pi_{\mathcal{J}}(h^*)$ when $\hat{h} < 1$.

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