EFFICIENT PATENT POOLS

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Efficient Patent Pools
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ABSTRACT

The paper builds a tractable model of a patent pool, an agreement among patent owners to license a set of their patents to one another or to third parties. It first provides a necessary and su±cient condition for a patent pool to enhance welfare. It shows that requiring pool members to be able to independently license patents matters if and only if the pool is otherwise welfare reducing, a property that allows the antitrust authorities to use this requirement to screen out unattractive pools.

The paper then undertakes a number of extensions. It evaluates the "external test," according to which patents with substitutes should not be included in a pool; analyzes the welfare implications of the reduction in the members' incentives to invent around or challenge the validity of each other's patents; looks at the rationale for the (common) provision of automatic assignment of future related patents to the pool; and, last, studies the intellectual property owners' incentives to form a pool or to cross-license when they themselves are users of the patents in the pool.

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1 Introduction

A patent pool is an agreement among patent owners to license a set of their patents to one another or to third parties. Patent pools have played an important role in industry since the 1856 sewing machine pool, although their number and importance considerably subsided in a hostile antitrust environment after World War II. Patent pools have been making a comeback in the last few years, and many believe that pools are bound to be as important or more important in the new economy as in traditional sectors. Innovations in hardware, software or biotechnology often build on a number of other innovations owned by a diverse set of owners.[1]

There is now widespread agreement among policymakers and economists that patent pools may benefit both intellectual property owners and consumers, provided that the pools include patents that are complementary or blocking. It is perhaps puzzling that so few pools have been formed in the recent past despite the favorable treatment the US Department of Justice (DOJ) and the US Federal Trade Commission (FTC) have given to pools of complementary innovations. This paper unveils some factors that either encourage or hinder the formation of a pool.[2] We analyze the strategic incentives to form a pool in the presence of current and future innovations that either compete with or are complementors to the patents in the pool.

A second focus of our analysis is the process through which competition authorities examine patent pools. A recent doctrine is that only "essential patents"

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[1]See Carlson (1999) and Gilbert (2002) for excellent historical perspectives on patent pools.

[2]The list of these factors is by no means exhaustive. For example, pools are less likely to form when the owners of intellectual property have different information, for example on the social value or the effective duration of individual innovations. Bargaining inefficiencies are then bound to arise. Also, when substantial decisions have to be made after the pool is formed, it may be difficult to design a proper governance structure, i.e., to align the interest of pool members.

be included in pools. In a number of cases, an independent expert has been assigned the role of ensuring that only essential inventions are added to the pool and removing patents that are no longer essential in the future. In the context of a pool defining a DVD-ROM and video standard, Assistant Attorney General Joel Klein defined essentiality in the following way:[3]

> "*Essential patents, by definition, have no substitutes; one needs licenses to each of them in order to comply with the standard.*"

In other words, the inventions covered by the patents in the pool must be complements (*internal test*); furthermore, each individual patent admits no substitute outside the pool (*external test*). One may wonder whether such standards are too strict or too lenient. By contrast, there have been historically (before 1995) almost no provisions relative to the inclusion of essential patents in pools.

Another feature of interest in the recent pools approved by American antitrust authorities is that patent owners retain a right to license their invention separately from the pool. 44% of the 63 pools included in the sample in Lerner et al. (2002) allow pool members to offer independent licenses outside the pool. When is the independent-licensing provision beneficial to the members of the pool? Is it a (presumably cheap) way of accommodating the concerns of antitrust authorities?

Shapiro (2001) uses Cournot (1838)'s analysis to point out that patent pools raise welfare when patents are perfect complements and harm welfare when they are perfect substitutes. While this is a useful first step in the antitrust analysis of patent pools, patents are rarely perfect complements or perfect substitutes; indeed, antitrust authorities sometimes wonder whether they are complements or

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[3]Letter of Joel I. Klein to R. Carey Ramos, Esq., June 10, 1999, http://www.usdoj.gov:80/atr/public/busreview/2485.wpd.

substitutes.[4]

Furthermore, most of the interesting policy issues do not arise in a world of perfect complementarity. For example, with perfect complements, the provision of independent licenses by patent owners and the exclusion of patents that are not unique paths would be meaningless. Another aspect of reality that is not well accounted for by the perfect-complements view of the world is the antitrust requirement of a fair and reasonable royalty as a condition for the formation of the pool. Such a condition can only prevent the emergence of a pool, even though a pool always enhances welfare under perfect complements.

Gilbert (2002) presents a graphical analysis, which suggests that instead of focusing on the restrictiveness of licensing terms in patent pools, antitrust authorities should attempt to overturn weak patents included in these arrangements.

The goal of this paper is to build a richer model, in which we can analyze existing institutional features and antitrust policy. The paper is organized as follows. Section 2 builds a model that allows the full range between the two polar cases of perfectly substitutable and perfectly complementary patents, and yet is tractable. It notes that except in the two polar cases, whether patents are substitutes or complements depends on the level of licensing fees. Section **??** provides a necessary and sufficient condition for pools to be pro-competitive in the absence of independent licenses. Section 4 shows that independent licenses can be used by competition authorities as a screening device. Section 5 analyzes the "external test," namely the absence of substitutes outside the pool. Section 6 asks whether pool formation dulls members' incentives to invent around patents or to challenge invalid ones, and derives the corresponding welfare implications. Section 7 analyzes the impact of pools on the members' incentives to discover

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[4]Besides, patents that are currently complements may in the future become substitutes as they enable new products that compete on the downstream markets.

new technologies. Section 8 generalizes the analysis to the case in which licensors are also licensees. Section 9 looks at asymmetric blocking patterns. Last, Section 10 summarizes the results and concludes with suggestions for further research.

2 Model

We begin with a very stylized model, and then consider progressively more realistic scenarios.

Intellectual property rights.

There are n owners, each of whom has a patent on one innovation. For the moment, we assume that the formation of the pool has no real effects on the amount of future innovation in the industry. We also initially assume that (a) the number n of patents that are included in the pool is cast in stone, (b) patent owners are not downstream users and therefore not potential licensees, and (c) the patents are non-infringing, in the sense that each is a valid patent (patents are, however, blocking in the sense defined shortly). We will relax these three assumptions in sections 7 through 9.

Demand for licenses.

Licensing involves no transaction or other costs. There is a continuum of potential "users" or "licensees". Users are heterogeneous and are indexed by parameter $\theta \in \left[\underline{\theta}, \overline{\theta}\right]$. User θ's gross surplus from using m, $1 \leq m \leq n$, innovations is

$$\theta + V\left(m\right).$$

Unless otherwise specified, the non user-idiosyncratic component $V\left(\cdot\right)$ is strictly increasing (we will occasionally consider "limit cases" in which $V(m) = V(m-1)$ for some m). Thus, the patents are blocking in the sense that it may be possible

to employ the technology with a subset of patents, but the use of the technology is optimized by combining as many patents as possible.

The range of the parameter θ of an idiosyncratic licensee's taste may include negative values (adopting the technology involves a fixed user cost) and/or positive ones (the technology enables the user to reap network externalities or to boost its research capability in the area). Letting F denote the cumulative distribution of θ, the demand for the bundle of the n innovations licensed at price P is

$$D\left(P - V\left(n\right)\right) = \Pr\left(\theta + V\left(n\right) \geq P\right) = 1 - F\left(P - V\left(n\right)\right).$$

We assume that the hazard rate $f \diagup [1 - F]$ is strictly increasing. This assumption (which is satisfied by almost all familiar distributions), ensures the strict quasi-concavity of the pool's maximization program. We will further assume for conciseness that the support $[\underline{\theta}, \overline{\theta}]$ is sufficiently wide so as to guarantee interior solutions. In particular, $\overline{\theta} + V(n) > 0$ (otherwise, the technology would never be used).

Motivation for the separability assumption.

There are several motivations for imposing this particular structure on user preferences: First, it simplifies the analysis and exposition, as it implies that all licensees select the same basket of licenses in the absence of a pool.

Second, the additive structure implies that it is optimal for a pool to offer solely a package license;[5] in other words, a pool cannot screen the user's type by offering, for example, a choice between the package license and licenses for

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[5]Which they usually do: Only 12% of the pools in the Lerner et al. (2002) sample offered menus of patents. To be sure, the absence of menu may have alternative motivations than that given here. The MPEG pool, for instance, considered offering menus, and ultimately rejected it. One big concern was the bargaining complexities that would be introduced, given the uncertainty about the valuation of many of the patents and the private information that many of the parties had about particular technologies.

subsets of patents.[6] A preference structure in which the user's type affects the marginal willingness to pay for patents would induce the pool to choose a menu of options. While such menus of options are interesting in their own right, they would add a distracting complication for the purposes of this paper.

Third, this structure will enable us to offer a clean description of the two constraints faced by an independent licensor. When contemplating a licensing fee increase, the independent licensor will worry either about her patent being excluded from the basket of patents selected by licensees, or, when retained in this basket, about the reduction in the overall demand for the basket. That is, the independent licensor may be constrained by either of two margins: the *competition margin* and the *demand margin*. Thus, the demand margin is said to bind in equilibrium if licensors could individually raise their license price without triggering an exclusion from the basket of patents selected by the licensees.
Substitutes and complements.

Let

$$w\left(m\right) \equiv V(m) - V\left(m-1\right) > 0$$

denote the users' willingness to pay for an mth patent when already having access to $m-1$ patents. Because (unless otherwise specified) V is strictly increasing, this marginal willingness to pay is strictly positive.

Definition 1: *The surplus function is concave if w is decreasing in m and convex if w is increasing in m.*

Unless otherwise specified, we will not impose specific restrictions such as convexity or concavity on the surplus function. First, the surplus function may

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[6]It can further be shown that pools do not benefit from using stochastic schemes, in which the number of patents received and the price paid by the licensee would be random functions of the licensee's announcement.

be neither concave nor convex.[7] Second, while there is some connection between concavity and substitutability, and between convexity and complementarity, the degree of complementarity cannot be defined solely on this basis, as we will see.

The traditional definition of substitutability (respectively, complementarity) is that two goods are substitutes (complements) if increasing the price of one raises (lowers) the demand for the other. *Two patents may be complements, however, at low prices and substitutes at high prices.* When the prices are low, users want to use all patents conditionally on adopting the technology; thus a decrease in the price of one patent attracts new users to the technology and boosts the demand for the other. By contrast, with high prices and provided the surplus function is sufficiently concave, users may want to use a single patent and thus the two patents compete with each other.[8] With two patents the only cases in which this reversal does not occur are the two polar cases of:

perfect substitutes: $V(n) = V(1)$, and

perfect complements (Shapiro-Cournot case): $\overline{\theta} + V(n-1) \leq 0$, and so no licensee benefits from (even a free) access to less than the full set of patents.

One of the tasks of Section 3 will be able to provide a measure of complementarity.

Demand margins for pool and independent licensors.

Let P^* denote the optimal price charged by the pool when patent owners cannot issue independent licenses:

$$P^* = \arg \max_{P} \{PD(P - V(n))\}. \tag{1}$$

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[7]For example, implementing the technology may require a minimum number m_0 of patents, but patents become competitors beyond that level ($w(m)$ small for $m \geq m_0$).

[8]More formally, if $p_1 = p_2 = p < V(2) - V(1)$, the two patents are complements (the demand for each is equal to $1 - F(p_1 + p_2 - V(2))$; if p_1 and p_2 both exceed $V(2) - V(1)$ (but are smaller than $\overline{\theta} + V(1)$), then the two patents are perfect substitutes.

Let $\hat{p}$ denote the price of individual licenses in the absence of a pool, but assuming that consumers must take all licenses or none (in other words $n\hat{p}$ is the price of a package license offered by a fictitious pool in which pool members would set royalties for their patents non-cooperatively):

$$\hat{p} = \arg \max_{p} \left\{ pD \left(p + (n-1)\hat{p} - V(n) \right) \right\}. \tag{2}$$

(2) has a unique solution. Furthermore, the monotone hazard rate condition implies that reaction curves $(p_i = R(\Sigma_{j\neq i}p_j))$ are downward sloping and have slope strictly less than 1 in absolute value. Thus there is a unique equilibrium in this hypothetical situation[9] and this equilibrium is symmetric, with prices all equal to $\hat{p}$.

As we will see, independent licensors may end up charging prices below $\hat{p}$, as licensees can pick a subset of patents. We will then say that licensors are constrained by the competition margin rather than by the demand margin.

Note that $\hat{P} = n\hat{p}$ satisfies

$$\hat{P} = \arg \max_{P} \left\{ \left[P - (n-1)\hat{p} \right] D(P - V(n)) \right\},$$

and so, by revealed preference,

$$\hat{P} > P^*. \tag{3}$$

Under noncoordinated pricing, each licensor does not internalize the increase in the other licensors' profits when demand for the package is increased by a reduction in her price. This result generalizes the Shapiro-Cournot argument: If

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[9]Suppose that $p_1 \leq \cdots \leq p_n$. Then

$$p_n - p_1 = R((p_2 + \cdots + p_{n-1}) + p_1) - R((p_2 + \cdots + p_{n-1}) + p_n) < p_n - p_1$$

unless $p_n = p_1$. Hence all prices are equal. The same will hold when we consider a subset of demand-constrained licensors in section 3.

the demand margin binds in the absence of pool, then a pool reduces the price paid by users.

3   When is a pool pro-competitive?

In this section, we compare the outcome of a pool in which members are not allowed to grant independent licenses with that in the absence of a pool. Consistent with antitrust authorities' focus, we analyze the competitive impact of the formation of a pool of existing patents (the *ex post* view). An *ex ante* view, accounting for the pre-pool incentive to engage in R&D and thus for the impact of the antitrust treatment of pools on the number n of innovations, might lead to a more lenient view concerning pool formation.[10]

Let us characterize the pure strategy equilibrium that prevails in the absence of a pool. Suppose that the n licensors charge prices $\mathcal{P} \equiv (p_1 \cdots, p_n)$, where without loss of generality, $p_1 \leq p_2 \leq \cdots \leq p_n$. A user's licensing decision can be decomposed into two steps. First, the user solves

$$\mathcal{V}\left(\mathcal{P}\right) = \max_{m \leq n} \left\{V\left(m\right) - \left(p_1 + \cdots + p_m\right)\right\}.$$

To break ties, we will assume that the users purchase the maximum number of patents in the optimal set whenever this program has multiple solutions.

Lemma 1.*In equilibrium all licensors have positive sales. They charge the same price if the demand margin binds, or if the competition margin binds and the surplus function is concave. Otherwise, there exists an equilibrium (on which we will focus) in which prices are equal.*

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[10]Such an approach would be in line with Denicolo (2002), who considers sequential innovation in a two-stage patent race model and argues that the prospect of an agreement between the owners of competing, sequential, but non-infringing patents increases investment in the second innovation and may raise welfare.

The proof of Lemma 1 is in the Appendix. Intuitively, with a zero marginal cost, a licensor with no sales would be better off lowering his price until users purchase a license. The existence of symmetric equilibria is unsurprising given the symmetric structure of the model. When the competition margin binds and the surplus function is nonconcave, asymmetric equilibria may arise, which we will ignore for expositional conciseness.

Let $p = z(n)$ denote the maximal possible price p satisfying:

$$V(n) - np = \max_{m < n} \{V(m) - mp\}.$$

In words, in a symmetric price configuration with price $z(n)$, licensors are constrained by the competition margin. Note that $z(n)$ is independent of the distribution of θ. In the concave case[11]

$$z(n) = w(n).$$

More generally

$$z(n) \leq w(n),$$

(since users can select $n - 1$ patents), possibly with strict inequality.[12]

Let

$$Z(n) \equiv nz(n),$$

Definition. *Fixing $V(n)$, patents are said to be more substitutable when $Z(n)$ decreases.*

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[11]For example, for $V(m) = (m/n)^{\alpha}$ with $\alpha < 1$, $z(n) = w(n) = 1 - ((n-1)/n)^{\alpha}$ converges to 0 as α converges to 0 (that is when patents become close substitutes).

[12]Suppose $n = 3$, $\{V(0) = 0, V(1) = 5, V(2) = 5$ and $V(3) = 8\}$ (a possible interpretation is that one patent suffices for a low-quality production, while the full set is necessary for a high-quality one). Then $w(n) = 3$ while $z(n) = 1.5$.

Note that $Z(n)$ is a measure of complementarity among pool patents given that the user has made the choice to go for this technology. Suppose, for example, that V is concave and so patents can be viewed as substitutes. If $\overline{\theta} < 0$ (using the technology covered by the patents involves a fixed cost), then the marginal benefit of the second, third,... patents may exceed the marginal benefit of the first. In that sense, the patents also exhibit some complementarity.

Proposition 1 *(absence of pool)*
(i) If $z(n) \, D' \left(Z(n) - V(n) \right) + D \left(Z(n) - V(n) \right) > 0$ then licensors are constrained only by the competition margin and charge equilibrium price $z(n)$.
(ii) If $z(n) \, D' \left(Z(n) - V(n) \right) + D \left(Z(n) - V(n) \right) < 0$, then licensors are constrained only by the demand margin, and $\widehat{p} < z(n)$.

Let us derive some comparative statics from this proposition. Let us index the distribution of types by a parameter γ: $F \left(\theta \mid \gamma \right)$. It is standard to compare distributions through their hazard rates. Parameter γ_1 corresponds to a lower demand (and higher elasticity) than parameter γ_2 if for all θ

$$\frac{f \left(\theta \mid \gamma_2 \right)}{1 - F \left(\theta \mid \gamma_2 \right)} < \frac{f \left(\theta \mid \gamma_1 \right)}{1 - F \left(\theta \mid \gamma_1 \right)}.$$

The following corollary follows directly from Proposition 1:

Corollary: *If the competition margin binds for parameter γ_1, then it binds a fortiori for parameter γ_2.*

In words, the competition margin is more likely to bind when the demand grows. The intuition is that if the demand margin binds, licensors increase their prices when the elasticity decreases. Licensees are then more tempted to do with a limited set of patents.

Proposition 2 *(normative analysis of pool)*

(i) A pool always increases welfare when the demand margin binds in the absence of pool.

(ii) A pool may increase or decrease welfare when the competition margin binds in the absence of a pool, depending on whether $P^* \lessgtr Z(n)$.

Part (i) of the proposition results from inequality (3). Part (ii) is a direct corollary of the fact that each licensor charges $z(n)$ when the competition margin binds in the absence of a pool.

Next note that, fixing $V(n)$, the pool price P^* depends only on the elasticity of the demand curve, and not on the substitutability $Z(n)$ among patents. Conversely, $Z(n)$ depends on the surplus function $V(\cdot)$, but not on the elasticity of the demand curve. This means that the competition and the demand margins are conceptually distinct.

A simple corollary of Propositions 1 and 2 is
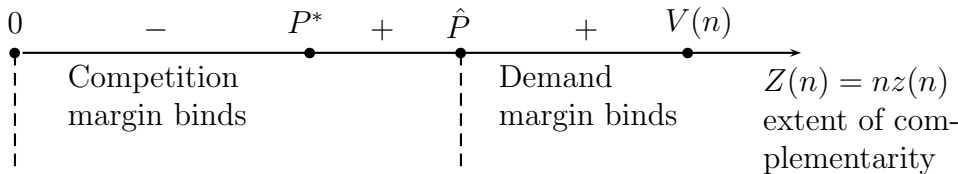
Proposition 3 *(substitutability among patents) As patents become more substitutable ($Z(n)$ decreases),*

(i) the competition margin is more likely to bind (since it binds if and only if $Z(n) \leq \widehat{P}$),

(ii) the pool is more likely to decrease welfare (it does so if and only if $Z(n) < P^*$).

The following figure summarizes the welfare analysis:

Figure 1

4 Independent licenses as a screening mechanism

Patent owners who request a statement of the Department of Justice's antitrust enforcement intentions with respect to a proposed pool arrangement usually include the provision that the individual patents that are part of the pool may still be licensed from the original patents' owners.[13] Indeed, this is one line of departure between a merger and a pool. In the context of a pool, the patent owners (the counterparts of the merging parties) still act independently and maximize their own profits. They just agree to market a jointly produced "good " – the package license – at some pre-agreed price – the royalty rate.

This common provision raises two related questions: First, what is the cost for pool members of including this provision (given that the pool administrator could offer individual patent licenses and not only the package license[14])? Second, would it be optimal for antitrust authorities to insist on this provision?

We consider a two-stage game following the constitution of the pool:

(i) The pool chooses a price P for its bundle (so as to maximize pool profit).

(ii) Owners non-cooperatively and simultaneously set license prices $(p_1, p_2, ..., p_n)$ for their individual patents.

We will say that the pool is weakly (strongly) *stable* to independent licensing if, when the pool charges P^*, the pool-profit maximizing price when there is no independent licensing, there exists a pure strategy equilibrium of stage (ii) such

[13]The independent licensing provision is by no means specific to the recent pools that have obtained review letters from the Department of Justice.

[14]For different specifications of user preferences, the pool might want to issue sublicenses; but recall that we have chosen licensees' preferences so that it is optimal for the pool to offer only the package license.

that (respectively, in all pure-strategy equilibria of stage (ii)) users buy solely from the pool.

Let us consider the two cases identified in Proposition 1.

Suppose first that the licensors are constrained by the *demand margin* in the absence of a pool. Suppose that the pool sets package price P^*, and so each licensor receives $p^* = P^*/n$ from each sale of the package if users prefer to buy the bundle to purchasing independent licenses. We know that $p^* < \widehat{p} < z(n)$. Suppose that the independent licensors offer prices $(p_1 \cdots, p_n)$ that induce users to buy independent licenses rather than from the pool. By the same reasoning as in section 3, all licensors then sell independent licenses, and so if license n is the highest price license, $p_n \leq z(n)$. Furthermore, by assumption,

$$V(n) - P^* < V(n) - \Sigma_1^n p_n.$$

Because $\Sigma_1^n p_n \equiv P < P^* < \widehat{P}$,

$$(P/n)D'(P - V(n)) + D(P - V(n)) > 0.$$

So marginal revenue is positive at least for licensor 1, the lowest-price independent licensor, who therefore would benefit from raising his price. Hence, $p_1 = \cdots = p_n = z(n)$. But then $P = Z(n) > P^*$, a contradiction. The pool is not only beneficial but also strongly stable.

Second, assume that the licensors are constrained by the *competition margin* in the absence of a pool. If the pool is beneficial, that is if $P^* < Z(n) < \widehat{P}$, the same reasoning as previously shows that the pool is strongly stable. Let us therefore assume that the pool reduces welfare in the absence of independent licensing:

$$Z(n) < P^* < \widehat{P}.$$

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Note first that the pool can't be strongly stable. Indeed there always exists a "run" in which licensors charge the competition margin $z(n)$ each (and by the local analysis of section 3, this is the only equilibrium in which the pool is upset). Licensors would be better off tying their hands to the mast, but cannot refrain from issuing independent licenses when others do.

Does there also exist a "no-run equilibrium" in which the pool is able to sell at price P^*? More generally, what prices $\overline{P}$ can the pool charge for the package license such that which the owners not offering independent licenses is an equilibrium? It must be the case that

$$V(1) - \left(\overline{P}/n\right) \leq V(n) - \overline{P},$$

since a deviator loses his dividend $\left(\overline{P}/n\right)$ when upsetting the pool.

For example, price P^* can be sustained in the concave case if and only if

$$V(1) - p^* \leq V(n) - P^*,$$

or

$$V(n) - V(1) \geq (n-1)\,p^*.$$

This inequality may or may not be satisfied (since $p^* > z(n) = w(n)$ by assumption).

Proposition 4 *(independent licensing by pool members)*
(i) A welfare-enhancing pool is strongly stable to independent licensing by pool members.
(ii) A welfare-decreasing pool is not strongly stable, and may or may not be weakly stable. When under the threat of a run, the pool cannot charge more than in the absence of pool. With better coordinated licensors, though, higher prices are sustainable, perhaps even the pool price in the absence of independent licensing.
(iii) For $n = 2$, individual licenses yield the same outcome as in the absence of

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a pool when the latter is welfare decreasing (and, from (i), have no effect if the pool is welfare enhancing).

We thus conclude that independent licensing is irrelevant for a welfare-enhancing pool, and may but need not reduce prices in the case of a welfare-reducing pool.

5 Essential patents and competition from outside the pool

Recall that there are two facets to essentiality: First, the patents included in the pool must be complements (internal test). Second, patents in the pool must not have close substitutes outside the pool (external test). The general fear is that the inclusion of a patent in the pool could *foreclose* competing patents outside the pools:[15]

> "*the inclusion in the pool of only one of the competing non-essential patents, which the pool would convey along with the essential patents, could in certain cases unreasonably foreclose the non-included competing patents from use by manufacturers; because the manufacturers would obtain a license to the one patent with the pool, they might choose not to license any of the competing patents, even if they otherwise would regard the competitive patents as superior.*"

It is not clear, though, that it is in the interest of pool members to include one of the competing patents. From the Chicago school critique of the foreclosure doctrine, as articulated in Whinston (1990), we know that it is often not in the

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[15]Joel Klein's ("Letter to Carey R. Ramos," June 10, 1999, page 11) response to the request by Toshiba and other patent owners to form a pool with regards to the DVD-ROM and DVD-video formats.

interest of firms to bundle competitive products with complementary noncompetitive ones, because the reduction in product variety in the competitive segment reduces the attractiveness of the complementary noncompetitive products. While bundling may in some specific cases benefit the owners of the bottleneck products, there is no presumption that it in general does.

To analyze the issue of over-inclusiveness and the possibility of foreclosure, suppose that there are $n + 1$ technologies. Each of technologies $i = 1, \cdots, n$ is a "unique path". Technology $n + 1$ is covered by two competing, non-infringing patents. The two patents are perfect substitutes from the point of view of licensees.

We will say that the pool is

- *non-inclusive* if it covers only technologies $1, \cdots, n$,

- *inclusive* if it covers technologies $1, \cdots, n$ as well as one of the patents for technology $n + 1$.

We now show that inclusiveness does not affect profits and welfare as long as technology $n+1$ has (as has been assumed until now) no alternative use, but that it may have a substantial impact if at least a small number of users are interested in technology $n + 1$ on a stand-alone basis (for a different type of application). So let us introduce another category of consumers, who are interested only in technology $n + 1$ and are willing to pay v> 0 for it. The timing goes as follows:

(1) The owners of technology $1, \cdots, n$ form a pool and decide whether to invite one of the owners of technology $n + 1$ to join it. In its charter, the pool decides whether the pool administrator is entitled to offer menus or only the entire package of the pool's technologies.

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(2) The pool administrator (who maximizes pool profit) and the independent
owner(s) of technology $n + 1$ set prices.

The choice of whether to allow pool administrators to offer menus and not
only the whole bundle that pools face here is a standard one. In the Lerner et al.
(2002) sample, only 12% of the pools elected to offer menus.

Suppose first that the pool is non-inclusive. Then Bertrand competition be-
tween technology $n + 1$ owners brings its price down to zero. The pool charges
either P^*, where

$$P^* = \arg\max \{PD\,(P - V\,(n + 1))\}$$

if the demand margin binds, or $\widetilde{P}$ given by

$$V\,(n + 1) - \widetilde{P} = V\,(1),$$

if the competition margin binds (i.e., if $V\,(n + 1) - P^* < V\,(1)$).

Suppose next that the pool is inclusive and owners are not allowed to license
their IP independently. If the pool elects to offer a menu, the outcome is the same
as under non-inclusiveness, since the pool and the independent owner compete à
la Bertrand in the market to the $(n + 1)^{\text{st}}$ technology. Suppose therefore that the
inclusive pool chooses not to offer menus.

If, under non-inclusiveness, the demand margin is binding $\left(P^* < \widetilde{P}\right)$, then the
pool charges P^*, and the independent owner focuses on the stand-alone demand
and charges $p_{n+1} = $v for technology $n + 1$. The pool's profit is unchanged, prices
are higher, but in this specification no deadweight loss is created. (If the stand-
alone demand were elastic, this third conclusion would not hold, and welfare
would decrease).

If the competition margin binds under non-inclusiveness $\left(P^* > \widetilde{P}\right)$, note first
that the independent owner can guarantee himself a minimal profit equal to v
times the stand-alone demand by charging $p_{n+1} = $v. This implies that there

exists $\underline{p} > 0$ such that prices $p_{n+1} < \underline{p}$ are strongly dominated for the independent owner. Hence the pool can charge at least $\widetilde{P}'$ such that

$$V(n+1) - \widetilde{P}' = V(1) - \underline{p}.$$

Hence the pool has increased its profit.[16]

Last, consider an inclusive pool allowing for independent licensing by its members. In (the unique pure-strategy[17]) equilibrium, Bertrand competition between the owners of technology $n + 1$ drives its price to zero. The outcome is then the same as for a non-inclusive pool.

Proposition 5 *(overinclusive pools) Consider a non-inclusive pool of n patents and an $(n + 1)^{st}$ technology covered by two noninfringing and competing patents and facing a stand-alone demand.*
(i) The pool cannot increase its profit by including one of the competing patents if the demand margin binds.
(ii) If the competition margin binds, the pool increases its profit by including one of the competing patents and welfare is then reduced. Independent licensing annihilates the impact of inclusiveness, though.

To increase its profit, the pool uses a "raise-your-user's cost" strategy: It reduces the competition for stand-alone uses of technology $n + 1$ by absorbing one of the competitors and by choosing to offer only the bundle of patents. When the competition margin is binding, the pool is constrained by its competition with technology $n + 1$, which is thereby relaxed. This raise-your-user's-cost strategy combines the raise-your-rival's-cost strategy of Ordover, Saloner and Salop (1990)

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[16]The price equilibrium (P, p_{n+1}) is here in mixed strategies, and is straightforward to derive.
[17]Such games also often have a mixed-strategy equilibrium (Baye-Morgan 1996). We have not investigated the existence of mixed-strategy equilibria in this particular game (which has asymmetric costs, due to the members' opportunity costs).

and Judd's (1985) avoidance of direct competition in a multi-product environment.

In Ordover et al., the vertical integration of an upstream firm with market power with a downstream producer reduces downstream competition by exposing the downstream competitors to the exercise of market power by the other upstream supplier. Ordover et al. assumed that the integrated upstream supplier can commit not to undercut its upstream rival for the business of unintegrated buyers even though such undercutting is profitable. A similar play happens here, and we motivate the commitment assumption through the choice of pool charter, namely of whether the pool administrator markets a package license only or offers a menu of choices to users.[18] The pool's strategy is also related to Judd's analysis of a multi-product firm, which exits one of the markets (here, the market for stand-alone uses) so as to soften price competition in that market and not to cannibalize another market (here, the market for bundles of patents).

Last, note the conditions needed for this strategy to be successful (besides the prohibition of independent licensing already mentioned):

(i) the competition margin must be binding. If the demand margin is binding, the name of the game for the n unique-path-technology patent owners is to get as low a price for the $(n+1)$th technology as feasible, which can be achieved equally well by Bertrand competition or by an inclusion in the pool;

(ii) inclusiveness and bundling must substantially reduce the intensity of competition on the market for stand-alone uses. If there were many substitute patents for technology $n+1$, then including one of them into the pool would hardly raise price for the $n+1$ th technology and therefore hardly reduce the competition for the pool when the competition margin binds;

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[18]Another difference with Ordover et al. is that the unintegrated "upstream" supplier serves the pool's users directly rather than through a downstream supplier.

(iii) on a related note, the price of the $(n + 1)$th technology would not increase if one of the suppliers of that technology kept its price constant for institutional reasons, as in the case of a software program covered by an open source license.[19]

6   Impact on circumvention strategies

Concerns have been raised concerning the possibility that pools dull incentives for future innovation. This section and the next analyze how pools change their members' incentives to a) circumvent (invent around) each other's patents and b) to discover new technologies related to the pool.

When users combine multiple patents, a decrease in the price of a patent augments the overall demand for the other patents. A patent owner may therefore want to take actions that lower the user price of other technologies. They may invent around these technologies or else attempt at getting the corresponding patents invalidated. The incentive to engage in such "circumvention strategies" are altered by the formation of a patent pool joint venture. This section investigates the private and social incentive for circumvention in a two-patent environment.

6.1   Pools and incentives to invent around

Consider for simplicity two patents, and suppose that the owner of patent 1 has the opportunity to develop a noninfringing perfect substitute for the technology covered by patent 2, at some cost $c \geq 0$.

a) *No pool.*

a1) In the absence of pool and when owner 1 does not circumvent, suppose first that the *demand margin* binds. Each owner charges $\widehat{p}$ such that

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$$\widehat{p} = \arg\max \left\{ pD\left(p + \widehat{p} - V(2)\right) \right\}.$$

The price of the bundle is then $\widehat{P} = 2\widehat{p}$.

Circumvention then enables owner 1 to bring the price of innovation 2 to zero and to charge $\widetilde{p} \equiv \min\{P^*, w(2)\}$, where $P^* = \arg\max\{pD(p - V(2))\}$ and $w(2) = V(2) - V(1)$, for patent 1. And so circumvention is profitable if and only if

$$\widetilde{p}D\left(\widetilde{p} - V(2)\right) - \frac{\widehat{P}}{2}D\left(\widehat{P} - V(2)\right) > c.$$

It then reduces the total price and thereby benefits consumers.

a2) When the *competition margin* binds, each owner charges

$$p = w(2) = V(2) - V(1)$$

in the absence of circumvention. The price of the bundle is then $W(2) = 2w(2)$.

When owner 1 invents around owner 2's patent, owner 1 still charges the same price, but there is more demand since technology 2 is now free. Thus, owner 1 invents around if and only if

$$w(2)D\left(w(2) - V(2)\right) - w(2)D\left(W(2) - V(2)\right) > c.$$

Again, consumers benefit from the circumvention strategy.

b) *Pool.*

We assume that there is no independent licensing and that the pool administrator is instructed to maximize pool profit. If owner 1 does not invent around patent 2, the pool charges P^* for the bundle and the pool profit

$$P^* D \left(P^* - V\left(2\right) \right)$$

is divided between the two members. (Profit may be shared unequally between the two members. Indeed, for c close to 0, owner 1 can guarantee herself a profit close to $P^* D \left(P^* - V\left(2\right) \right)$ when innovations are almost perfect complements, by not entering a pool and inventing around owner 2's patent. Hence, an unequal division of pool profit[20] may be required for pool formation.)

Suppose now that owner 1 invents around patent 2. Either $P^* < w(2)$ and the pool keeps charging P^* (circumvention is irrelevant); or $P^* > w(2)$ and the pool *may* need to reduce its price.[21] In either case, circumvention brings no new revenue (and may jeopardize the existing one) for owner 1.

But even if the absence of pool induces circumvention, the welfare analysis may turn in favor of the pool. Take for instance case a1) (the demand margin binds) when $\widetilde{p} = P^*$. The final outcome is then the same as in the presence of a pool, except for the wasted duplication cost c. Owner 1 expands resources in order to reduce the price of complementary technology 2, and this cost could be avoided by the formation of a pool.

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[20] An example of a patent pool in which royalties were distributed (very) unequally is the 1917 Manufacturers Aircraft Association, in which members had to pay per plane \$135 to Wright-Martin Aircraft Corporation and \$40 to Curtiss Aeroplane and Motor Corporation.

[21] Whether it does so depends on whether αP^* is larger or smaller than $w(2)$ where $\alpha \leq 1$ is owner 1's share of dividends in the pool. Owner 1 may be reluctant to offer a low price for its me-too version of technology 2 since this cannibalizes the pool (from which he receives a share of the dividends) with an inferior product (with quality difference $w(2)$).

Proposition 6 *(incentives to invent around) Consider a two-member pool in which the owner of patent 1 can invent around patent 2.*

(i) Owner 1 never invents around patent 2 when a pool is formed.

(ii) Owner 1 invents around patent 2 in the absence of a pool if the cost of doing so is small enough. Circumvention in the absence of pool may, however, be welfare-dominated by a pool.

The analysis is summarized in Figure 2. That a pool has a negative welfare impact when $w(2) < P^*/2$ results from Proposition 4 (in the absence of circumvention possibility, pools reduce welfare) and from our observation that the circumvention possibility reduces the social desirability of a pool.

	0		$\frac{P^*}{2}$ $\hat{p}$	P^*	$V(2)$
Binding constraint (no pool)		Competition margin		Demand margin	$w(2)$ (extent of complementarity)
Incentive to invent around (no pool)		$w(2)D(w(2) - V(2))$ $-w(2)D(2w(2) - V(2))$	$w(2)D(w(2)$ $-V(2))$ $-\hat{p}D(2\hat{p}$ $-V(2))$	$P^*D(P^* - V(2))$ $-\hat{p}D(2\hat{p} - V(2))$	
Welfare impact of circumvention (if it occurs)			$+$		
Welfare impact of pool		$-$	$?$	$+$	

Figure 2

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6.2 Invalidation of a bogus patent as a circumvention strategy

Concern has been repeatedly voiced as to the possibility that patent pools be used to shelter bogus patents. For example, in 1998 the US Federal Trade Commission challenged the Summit-VISX pool because, *inter alia*,[22] it was shielding an invalid patent. The reasoning was that one company would have sued the other for use of an invalid patent, but for the creation of the pool.

While widely accepted, the argument that the inclusion of bogus patents in a pool is welfare detrimental has not been fully articulated. With perfect complements, for example, the inclusion of an invalid patent into a pool leads to a package-price reduction if the cost of obtaining an invalidation is too high, and to the economizing of legal costs if the latter are low enough to justify the invalidation process; in either case, the inclusion of the bogus patent into a pool is welfare enhancing.

Let us therefore analyze the bogus patent problem in a bit more detail. Suppose that there are two owners, and that patent 2 can at some cost c be proved invalid. We assume that patent 2 was actually covered by prior art or else obvious. Furthermore, only owner 1 can initiate the invalidation process; the other stakeholders, the users, are too dispersed and are assumed not to be able to solve their collective action problem (recall that proving that patent 2 is invalid is costly).

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[22]The companies were also charged with unlawful price fixing involving their patent pool.

Consider the following timing in the absence of a pool:[23]

(i) Owner 1 decides on whether to incur cost c to make patent 2 invalid. If he does, then technology 2 is available to everyone for free.

(ii) Owner 1 and (if his patent is not proved invalid) owner 2 set prices for their licenses.

Note that the impact of the invalidation process is the same as that of the circumvention strategy of Section 6.1: It brings the price p_2 of technology 2 down to zero. Thus the analysis of the private and social impacts of the invalidation process is identical to that of Section 6.1.

In case of a pool, owner 1 can still call for an invalidation, but in that case he clearly "shoots himself in the foot" since he creates more competition for the pool package on which he receives royalties. Thus the pool outcome is also the same as in Section 6.1.

Proposition 7 *(bogus patent). Suppose that $n = 2$ and that patent 2 can at some cost c be challenged by the owner of patent 1 for invalidation, as it is obvious or covered by prior art.*

(i) Owner 1 does not challenge the bogus patent 2 when a pool is formed.

(ii) Owner 1 challenges the bogus patent 2 in the absence of a pool if the cost c is small enough. Such a challenge may, however, be welfare-dominated by a pool.

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[23]We could alternatively consider the "reverse timing" in which owner 2 is able to (long term) commit to a price p_2 for licenses before owner 1 decides whether to sue. Then owner 2 practices "limit pricing" so as to fend off a lawsuit by owner 1: It sets p_2 so that

$$\max_{p_1 \leq w(2)} \{p_1 D (p_1 - V(2))\} - \max_{p_1 \leq w(2)} \{p_1 D (p_1 + p_2 - V(2))\} = c.$$

The analysis is then similar, although a bit more complex than that developed below.

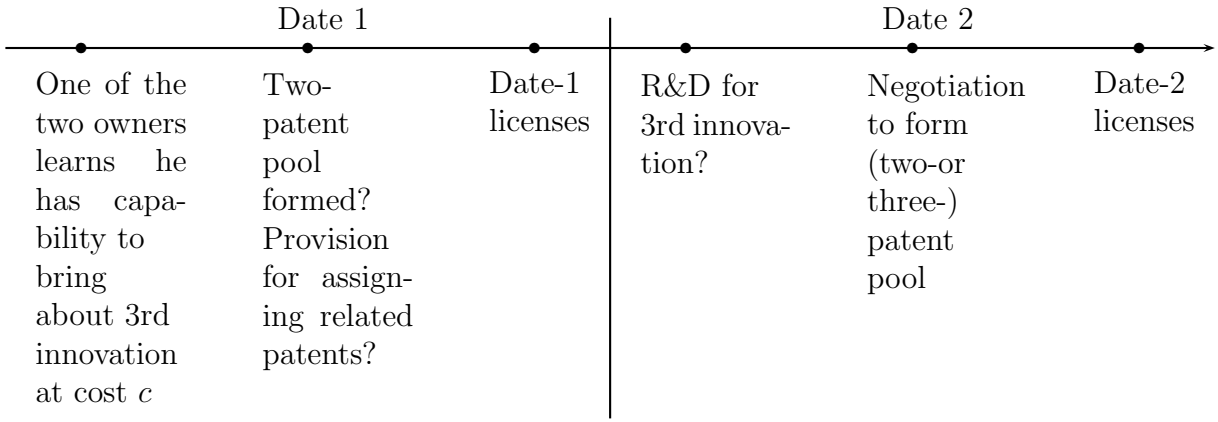# 7 Assignment of future related patents to the pool

Pools can affect the innovation market by requiring that their members assign their future related patents that are deemed essential to the pool. There is no denying that such a term (which can be found in 46 of the 63 pools studied by Lerner et al. (2002)) has the potential to dull incentives for innovation and to thereby reduce welfare.

This section instead focuses on the efficiency defense for the provision. A recurrent concern of pools is that they may be held up in the future by innovations brought about by their members. The duty to disclose any patent application that is relevant to the pool addresses the concern that an existing innovation will in the future confront the pool. By contrast, we are interested in innovations that can be but are not yet made, or else whose current existence can be effectively concealed by the members.

Let us for simplicity consider a two-patent, two-member pool ($n = 2$). A third innovation is feasible at some cost c, which only one of the two members has the capability to discover. For simplicity, we assume that all patents (whether there are two or three) are sufficiently complementary so that it is always the demand margin that binds.

Consider the following two-period timing:

At date 1, one of the owners, owner 2, say, identifies that he has the capability to bring about the third innovation. The two owners then bargain on whether to form a two-patent pool and, if so, whether to add a term specifying that related patents (here, the patent on innovation 3) must be assigned to the pool. The two existing patents are then licensed, either by their owners, if a pool has not

	Date 1			Date 2	
One of the two owners learns he has capability to bring about 3rd innovation at cost c	Two-patent pool formed? Provision for assigning related patents?	Date-1 licenses	R&D for 3rd innovation?	Negotiation to form (two-or three-) patent pool	Date-2 licenses

been formed, or as a package by the pool otherwise. At date 2, owner 2 decides whether to spend c to innovate. Then, a three-patent pool is formed if he has innovated, or a two-patent pool is formed if he has not innovated and no pool has been formed at date 1. At date 2, licenses are issued to the users.

Letting π_i^t denote owner i's profit at date t, owner i's discounted payoff is (proportional to)

$$X\pi_i^1 + (1 - X)\,\pi_i^2$$

(where for interest rate r and length T of period 1, $X \equiv 1 - e^{-rT}$. So $X \simeq 0$ if T is low, and $X \simeq 1$ if T is large).

We assume that

(i) all bargaining is Nash bargaining: Owner i obtains

$$\pi_i = \frac{\pi^* + [\pi_i\,(0) - \pi_j\,(0)]}{2},$$

when the joint profit to agreeing is π^*, and the status-quo profits in the absence of agreement are $\pi_.\,(0)$;

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(ii) pool members share royalties equally (we will relax this assumption later);

(iii) pool members are cash constrained: They don't have enough liquidity to operate ex ante lump sum transfers between themselves (see motivation below).

Let

$$\pi_n^* \equiv \max \{PD(P - V(n))\}$$

denote the profit of a n-patent pool.

Let us work by backward induction. Suppose that owner 2 has innovated and consider the negotiation for the formation of a three-patent pool. In the presence of an existing *two-patent pool*, and in the absence of inclusion of the third patent into the pool, the pool administrator then charges P for the bundle of the first two patents, and owner 2 charges p_3 for the third patent. They solve, respectively (assuming that pool royalties are shared equally):

$$\max_P \{PD(P + p_3 - V(3))\},$$

and

$$\max_{P_3} \left\{ \left(\frac{P}{2} + p_3 \right) D(P + p_3 - V(3)) \right\}.$$

The first-order conditions imply that

$$P = 2p_3.$$

Hence, if the renegotiation to a more efficient three-patent pool (that eliminates the double marginalization) were to break down, owner 2 would make *twice as much* profit as owner 1 ($\pi_2(0) = 2\pi_1(0)$). This puts him in a very strong bargaining position.

By contrast, suppose that no such two-patent pool was formed at date 1. Then, owner 1 charges p_1 for patent 1, and owner 2 charges some P for the

bundle of patents 2 and 3. They solve, respectively,

$$\max_{p_1} \{p_1 D \, (p_1 + P - V \, (3))\},$$

and

$$\max_{P} \{PD \, (p_1 + P - V \, (3))\}.$$

Hence

$$p_1 = P.$$

Thus, if the renegotiation to the three-patent pool were to break down, owner 2 would make *as much* profit as owner 1 ($\pi_2 \, (0) = \pi_1 \, (0)$). His bargaining position is thus not as strong as in the presence of a pool. Indeed, they share π_3^* equally, exactly as when a pool has been formed at date 1 with the provision that new patents are assigned without compensation to the pool!

Let us now turn to owner 2's incentive to bring about the third innovation. He does so if and only if

$$c \le c^* = \frac{\pi_3^* - \pi_2^*}{2}$$

if either no pool was formed at date 1 or a pool with an automatic assignment was formed, and if and only if

$$c \le c^{**} = \frac{[\pi_3^* + (\pi_2 \, (0) - \pi_1 \, (0))] - \pi_2^*}{2}$$

(where $c^{**} > c^*$) if a pool without automatic assignment was formed. The ability to hold-up the pool thus raises owner 2's incentive to innovate.

Last, we look at owner 1's incentive to join a pool at date 1:

Proposition 8 *(i) Owner 1, when contemplating whether to form a pool at date 1, faces a trade-off between delaying the formation of a pool and creating a double*

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marginalization at date 1 (this cost is small if X is small), and avoiding the hold-up by not joining the pool. An alternative way to prevent this hold-up is to insist on an automatic assignment term; this term however may dull the incentive for innovation.

If $c \leq c^*$, then owner 1 accepts (and actually is eager to) join a pool with automatic assignment.

If $c > c^*$, then owner 1 accepts to join a pool without automatic assignment.

(ii) A legal prohibition on automatic assignments prevents the formation of a pool whenever $c \leq c^*$ and $X \leq X^*$ for some $X^* \in (0, 1)$, and is then welfare decreasing (it is neutral otherwise).

Remark 1: Note the role of assumption (iii). The impossibility to make *ex ante* lump sum transfers implies that owner 1 cannot obtain compensation for the hold-up. Hence owner 1 can protect himself from a hold-up only by insisting on an automatic assignment (which does not discourage innovation if the latter's cost is below c^*) or by not joining a pool. A legal prohibition on automatic assignments may lower welfare by forcing owner 1 to protect himself in a socially wasteful manner.

Remark 2: Turning to assumption that pool members share royalties equally, when a legal prohibition on automatic assignments prevents the pool from forming ($c \leq c^*$ and $X \leq X^*$), note that owner 2 can use the sharing of royalties in order to convince a reluctant owner 1 to create a two-patent pool. That is, royalty sharing favorable to owner 1 can be a substitute for a lump sum transfer.[24] Note

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[24]In the presence of a third innovation, suppose that owner i receives a share α_i ($\alpha_1 + \alpha_2 = 1$) of the royalties of the two-patent pool. Then owner 2's choice of licensing price p_3 solves

$$\max_{p_3} \left\{ (\alpha_2 P + p_3) D (P + p_3 - V(3)) \right\}.$$

In particular, owner 2's taking no royalties eliminates the hold-up problem: For $\alpha_2 = 0$, $P =$

also that in a more general environment, in which, say, the innovation cost were random, one would expect owner 2's royalty rate to be "backloaded" (that is, increased when innovation 3 is added to the pool) so as to enhance his incentive for innovation.

8   Licensors are also licensees

We have until now analyzed pools whose members are upstream patent owners and license to third-party downstream users. Let us now allow licensors to be also licensees. We focus on the other polar case in which the pool does not offfer licenses to third parties. Its n members form a symmetric n-firm downstream oligopoly. Users pay royalty rate (or access charge) a to the pool, whose profit is then redistributed equally among its members. For simplicity, let us assume that $n = 2$.

Patent owners who are also downstream competitors will never want to join a pool, if the pooling of their patents make them undifferentiated. To account for pool formation we therefore assume that the two firms are differentiated in two ways (the following analysis is inspired by the "double differentiation model" in Hausman et al. (2001)). The first dimension of differentiation is technology unrelated; the two firms are located at the two extremes of an Hotelling segment $[0, 1]$. Consumers are located uniformly on the segment and incur unit transportation cost t.

Second, patents 1 and 2 describe two technologies that are differently suited to the needs of the consumers. Namely, patents 1 and 2 are located at the two extremes of an Hotelling segment $[0, 1]$, and consumers are uniformly[25] distributed

$\alpha_1 P = p_3$. Such an arrangement, however, need not be agreeable to owner 2.

[25]The results in Hausman et al. hold for arbitrary distributions. The assumption of uniform distributions is used here to show that the markup increases with differentiation, and is much

along that segment (independent of their location in the other dimension), with transportation cost u per unit of distance.

Pooling the patents then allows both firms to offer a better service to consumers: each can offer the patent 1- and patent 2-enabled versions and so consumers haver a better match for their needs.

(a) *No pool.*

If x and y denote the locations of a consumer in the "natural" differentiation space and the technology space, and p_1 and p_2 denote the prices charged by the firms in the absence of pool, then the consumer selects firm 1 if and only if

$$p_1 + tx + u\,y \le p_2 + t\,(1 - x) + u\,(1 - y).$$

The outcome is the Hotelling outcome $(p^*,\ p^*)$ for marginal cost 0 and a differentiation that is the convolution of the two differentiations.[26] One has $p^* > t$ (unless $u = 0$, in which case $p^* = t$).

(b) *Pool.*

In case of a pool with royalty rate a, the opportunity cost of stealing a customer from one's rival is equal to a (given that the dividend $a/2$ accrues to the firm regardless of who serves the consumer). Each firm offers the patent 1- and patent 2-enabled versions and the unique price equilibrium is:

$$p^* = a + t.$$

(see Hausman et al. 2001). The intuition is that each firm charges a fee to consumers equal to the opportunity cost of acquiring the consumer plus the dif-

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stronger than needed.

[26] The resulting differentiation can be represented by a variable $X \in \left[0, 1 + \frac{u}{t}\right]$ and a transportation parameter t. The variable X has distribution given by $L(X) \equiv \Pr\!\left(x + \frac{u}{t}y < X\right) = \int_0^1 K\left(X - \frac{u}{t}y\right) h(y)\,dy$, where K and H denote the cumulative distributions (here, the identity on $[0, 1]$) of variables x and y.

ferentiation markup, and lets the consumers select the version that best suits them by not charging different prices for different versions.[27]

Even if $a = 0$, a pool may benefit the two firms because of demand augmentation. To capture this demand augmentation effect in a tractable way (that is, not interferring with the double-differentiation analysis above), let us assume that users are ex ante identical.[28] At "search or set up cost" s, they adapt their technology to that covered by the two patents, and learn about their own locations in the two spaces. Letting v denote the gross surplus, a user spends the search cost s if and only if $s \leq s^*$, where

$$s_P^*(a+t) = \mathrm{v} - E_{(x,y)} \left\{ \min_{\{i,j\}} \{a + t + t \mid x - x_i \mid +u \mid y - y_j \mid\} \right\}$$

under a pool, and

$$s_{NP}^*(p^*) = \mathrm{v} - E_{(x,y)} \left\{ \min_{\{i\}} \{p^* + t \mid x - x_i \mid +u \mid y - y_i \mid\} \right\}$$

in the absence of a pool. The distribution of s in the population is given by the cumulative $G(s)$, and so total demand is $G(s_P^*)$ under a pool and $G(s_{NP}^*)$ in the absence of a pool. We assume that the hazard rate g/G is decreasing so as to guarantee the concavity of profit functions. A pool creates a better fit and, keeping prices constant, increases demand.

The per-firm profit is

$$\pi_P(a) = \frac{G(s_P^*(a+t))}{2}(a+t)$$

under a pool, and

$$\pi_{NP} = \frac{G(s_{NP}^*(p^*))}{2}p^*$$

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[27]The result is obvious when the two patents are incorporated in the good (say, a software) manufactured by the firms, which then do not offer multiple versions. The intuition given above refers to the versioning case.

[28]This simplification is also used in Hausman et al (2001).

in the absence of a pool.

The monotone hazard rate condition together with the linearity of $s_P^*(\cdot)$ imply that π_P is concave. Last, note that $s_P^*(p) < s_{NP}^*(p)$ for all p (a pool allows for better quality offers). We can thus conclude that:

Proposition 9 *(i) There exists $\underline{a}(t,u) \geq 0$ and $\overline{a}(t,u)$ such that a pool is formed if and only if $a \in [\underline{a}(t,u) , \overline{a}(t,u)]$.*

(ii) Firms may have too little incentive to form a pool if a is constrained to be equal to 0. Provided that the no-pool equilibrium price p^* increases with the firms' patent-related differentiation parameter u, a pool forms (under the no-royalty constraint) if patents are close substitutes (u small) or very differentiated (u large), but may not form for intermediate values. A no-royalty pool never forms if the firms are little differentiated along the non-patent-related dimension.

(iii) The socially optimal royalty rate among those that induce the firms to form a pool is $a = \underline{a}$.

9   Asymmetries in blocking patterns

This section shows how our model can help study asymmetric situations in which, say, subservient patent 2 improves patent 1, i.e., enables better products than patent 1 alone, but has no value on a stand-alone basis. That is, patent 2 is valueless without patent 1, while patent 1 on a stand-alone basis delivers gross surplus $\theta + V(1)$ to user θ (whom we assume to be a third-party user). For simplicity, we assume that $n = 2$.

As it turns out, the antitrust implications of pools are rather straightforward in this case, as shown by the following proposition proved in the Appendix:

Proposition 10 *With the asymmetric, dominant / subservient pattern,*

(i) independent licenses have no bite, and

(ii) pools unambiguously enhance welfare.

The key to understanding why pools are always welfare enhancing here is to note that, by assumption, the subservient patent is valueless on a stand-alone basis, and so *the demand margin always binds for the dominant patent*; this property creates a potential double marginalization, and thereby a potential social gain to the formation of a pool.

Remark: The analysis of Section 6.1 can be extended to the asymmetric blocking pattern in order to qualify Proposition 10. In particular, the owner of the subservient pattern may be able to invent around the dominant pattern, creating strong Bertrand competition if the subservient patent brings about only a minor improvement. The formation of a pool dulls this incentive if either the pool prohibits independent licensing or the pool allows it and gives a high share of the royalties to owner 2.

10   Summary and concluding remarks

The paper has built a tractable model of a patent portfolio, that allows for the full range of complementarity/substitutability. In the absence of pool, the demand margin binds if an increase in the license price of a patent leads to a reduction in the demand for the patent basket; the competition margin binds if it leads to the exclusion of the patent from the basket selected by users. Let us first summarize the main insights:

a) *Pro-competitive pools*: A pool is more likely to be welfare-enhancing if patents are more complementary. That the demand margin binds in the absence of pool is a sufficient, but not a necessary condition for a pool to be welfare-enhancing.

b) *Independent licenses as a screening device*: A pool is never affected by the possibility of independent licensing if and only if the pool is welfare-enhancing. Furthermore, with only two patents, independent licensing always yields the same outcome as in the absence of a pool if the pool is welfare-decreasing in the absence of independent licenses. With more than two patents and a welfare-decreasing pool, independent licensing in general gives rise to multiple equilibrium outcomes.

c) *External test*: The inclusion of one of a set of substitute patents into the pool under some circumstances decreases welfare. This detrimental effect can be avoided through the use of independent licenses.

d) *Circumvention strategies*: Pools dull their members' incentives to invent around or to try to invalidate pool patents held by other members. Even so, pools may have beneficial effects, except in the case of strong substitutes.

e) *Licensors as licensees*: Pools reduce the differentiation of downstream users when the latter are the licensors. A positive royalty rate in such pools/cross licenses may be what it takes to induce the welfare-enhancing sharing of innovation among competitors, although public oversight of the royalty rates may still be needed in order to prevent excessive levels.

f) *Assignment of future patents*: The provision of assigning future related patents to the pool, while having a potential anticompetitive effect may be a response to the possibility of future hold-up problems.

This paper is a first step in the analysis of factors that encourage or hinder the formation of patent pools and of the checklist that should be employed by competition authorities in their review of pools. Looking forward, our theoretical understanding of patent pools should be deepened in several directions.

First, our assumption of separability of user preferences, while simplifying the analysis, focused it on package licensing and ruled out price discrimination

through menus.

Second, we have assumed an all-or-nothing pool. In practice, pools may be formed with a subset of the relevant patents, which raises the interesting issue of holdouts.

Third, we focused on the polar cases of a closed pool and pure third-party licensing by the pool. The intermediate case of mixed third-party and member licensing raises the issues of the impact of differential treatment among licensees and of its consequences for the choice between cross licensing and pool formation.

Fourth, pools often seem to reflect equal-treatment preoccupations despite asymmetries in the importance of innovations, in the status of members (licensing and non-licensing owners), or in the ability to clone another member's innovation; theoretical work should be devoted to the understanding of equal treatment in such circumstances.

Last, one would want to compare the merits of pools and standard setting processes. These and the many other important questions related to pools lie outside the limited scope of this paper, which we hope will encourage research in these directions.

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Appendix

Proof of Lemma 1

Let $m(\mathcal{P})$ denote the number of licenses for price configuration $\mathcal{P}$ (with $p_1 \leq p_2 \leq \cdots \leq p_n$). The second step of the user's optimization problem is to compare $\theta + \mathcal{V}(\mathcal{P})$ and 0.

(i) A first observation is that, if there are licenses in equilibrium, then all independent licensors have positive sales. That is, for equilibrium prices, $m(\mathcal{P}) = n$. If this were not the case, licensor n (the highest price licensor by assumption) would make no profit and so would gain by charging any price exceeding 0 but smaller than $w(m(\mathcal{P}) + 1)$, as such a price would induce users to license her technology.

(ii) As already discussed, a licensor may be constrained either by the competition margin or by the demand margin. So let us divide licensors accordingly: those, $i \in N_C$, for which a marginal increase in the licensing fee would lead to an exclusion of the patent from the users' basket and those, $i \in N_D$, for which this is not the case. Licensor $i \in N_D$ is purely demand constrained and solves:

$$\max_{p_i} \left\{ p_i D \left(p_i + \sum_{\substack{j \in N_D \\ j \neq i}} p_j + \sum_{j \in N_C} p_j - V(n) \right) \right\}.$$

By the same reasoning as in Section 2, this implies that all licensors in N_D charge the same price p_D. Licensors in N_C need not charge the same price (although they necessarily do in the concave case as they then charge $w(n)$). For expositional simplicity we will focus on the symmetric case in which they all charge price p_C (results do not hinge on this).

Next suppose that $p_C < p_D$. Letting m_C and m_D denote the number of elements in N_C and N_D, the fact that the competition margin binds for patents in N_C

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implies that

$$\max_{\{k \leq m_C - 1, \, \ell \leq m_D\}} \{V(k + \ell) - kp_C - \ell p_D\} = V(n) - \Sigma_1^n p_i$$
$$\leq \max_{\{k \leq m_C, \, \ell \leq m_D - 1\}} \{V(k + \ell) - kp_C - \ell p_D\}$$

But the inequality implies that licensors in N_D are competition constrained (they can't raise their price without being excluded from the basket), a contradiction. Last, it is easy to see that $p_C = p_D$: Because

Proof. $\quad p_D D' + D = 0,$

then

$$p_C D' + D < 0 \qquad \text{if} \ \ p_C > p_D,$$

and so licensors in the competition constrained set would be better off lowering their licensing fee. ∎

Proof of Proposition 10

(i) To prove proposition 10, let us first show that the two members can make an independent licensing provision irrelevant by structuring the royalty shares α_1 and α_2 $(\alpha_1 + \alpha_2 = 1)$ adequately.[29]

An unconstrained pool charges P^* so as to solve

$$\max_P \{PD(P - V(2))\}.$$

Suppose that the owner of patent 2 receives royalty share α_2 such that

$$\alpha_2 \leq \frac{w(2)}{P^*} = \frac{V(2) - V(1)}{P^*}.$$

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[29] This assumes that the members can always make a lump-sum transfer between themselves in order to implement any desired profit allocation. Lump sum transfers may not be needed though: Owner 1 makes the monopoly profit π_1^* corresponding to the dominant patent before they reach an agreement and so will insist on a higher royalty share. For example, under Rubinstein-Stahl alternating-moves bargaining (with quick offers), owner 1 receives share $\alpha_1 = \frac{1}{2} + \frac{\pi_1^*}{2\pi_2^*}$ of pool profit π_2^*.

Then, provided that owner 2 cannot license his patent individually without in-fringing upon owner 1's intellectual property, the pool's optimal price P^* is not upset by independent licensing. Owner 1 benefits from selling independent li-censes only if he charges price p_1 that compensates for the lost pool royalties:

$$p_1 \geq \alpha_1 P^*,$$

and that makes the independent license more attractive than the package license:

$$V(1) - p_1 \geq V(2) - P^*.$$

These three inequalities are inconsistent.

(ii) Let $\widetilde{P}_k$ denote the quality-adjusted price for k patents:

$$\widetilde{P}_2 \equiv P - V(2) \quad \text{and} \quad \widetilde{P}_1 \equiv p_1 - V(1),$$

where p_1 is now the price charged by owner 1 in the absence of a pool. The pool solves:

$$\max_{\widetilde{P}_2} \left\{ \left[\widetilde{P}_2 + V(2) \right] D\left(\widetilde{P}_2 \right) \right\}.$$

In the absence of a pool, owner 1 charges p_1 and owner 2 charges p_2, where

$$p_2 \leq w(2) = V(2) - V(1),$$

since patent 2 has no value on a stand-alone basis. Either $p_2 < w(2)$, and so the demand margin binds for both patents. The same reasoning as in Section 3 then shows that a pool eliminates the double marginalization and therefore raises welfare.

Or $p_2 = w(2)$, and so owner 1 solves

$$\max_{p_1} \left\{ p_1 D\left(p_1 + p_2 - V(2) \right) \right\} = \max_{p_1} \left\{ p_1 D\left(p_1 - V(1) \right) \right\}.$$

Equivalently, owner 1 chooses a quality-adjusted price $\widetilde{P}_1$ so as to solve:

$$\max_{\widetilde{P}_1} \left\{ \left[\widetilde{P}_1 + V(1) \right] D \left(\widetilde{P}_1 \right) \right\}.$$

Revealed preference implies that

$$\widetilde{P}_1 > \widetilde{P}_2,$$

and so users are better off under a pool, which furthermore yields higher industry profit.∎