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Corinne Langinier

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Abstract

Basic innovations are often fundamental to the development of applications that may be developed by other innovators. In this setting, we investigate whether patent pools can rectify the lack of incentives for developers to invest in applications. Following Green and Scotchmer (1995), we also wonder whether broad basic patents are necessary to provide enough incentives for basic innovators. We show that patent pools are more likely to be formed with patents of very different breadth, or patents of similarly wide breadth. Further, even though patent pools rectify the problem of developers' incentives, they may reduce the incentive for doing basic research.

Keywords: Patent pool, innovation, breadth

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*Iowa State University, Ames. langinier@econ.iastate.edu

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1 Introduction

In the area of biotechnology, follow-up innovations are often built on several basic innovations, and cannot be developed without them. Inventions such as methods to isolate and locate gene sequences possess the characteristics of public goods. These basic inventions have no value by themselves, but they permit to develop subsequent valuable applications. Furthermore, basic innovations and applications are usually developed by different companies.[1]

Two important incentive problems emerge from sequential innovations. First, basic innovators must be given enough incentive to promote their innovations. The literature on sequential innovation has mainly focused on how to protect the first generation of innovators against future innovators. In other words, it is concerned with the transfer of profit from second generation innovators to the initial innovators in order to promote basic innovations (Scotchmer, 1996; Green and Scotchmer, 1995; Chang, 1995). In this context, Green and Scotchmer (1995) show that first generation innovators should be given broad protection when second generation innovations can only be obtained by an outsider.[2]

Second, follow-up innovations may not be brought about when developers decide not to pursue research if it is built on several basic innovations (Merges and Nelson, 1994). Indeed, if basic patents are too broad, follow-up innovators may have to pay too many fees to be able to develop applications. This is referred by Heller and Eisenberg (1998) as the "tragedy of anticommons." There are too many door keepers, and to build on previous innovations an innovator needs the permission of too many patentholders (Shapiro, 2001). This second problem

[1] For instance, a public laboratory or a research department at the university can develop basic innovations while letting the private sector develops applications.

[2] In the case of a long sequence of innovation, the optimal scope of patents is provided to stimulate R&D investment (O'Donoghue, Scotchmer and Thisse, 1998).

is specially acute in biotechnology. A recent survey of laboratory physicians shows that because of patents one fourth have abandoned a clinical test that they have developed, and almost one half report that they have not developed a test for fear that they would be sued.[3] One of the solutions is to license patents in a patent pool that is an agreement between two or more patentholders to license one or more of their patents to one another or to third parties (Merges, 1999). Hence, patent pools play an important role in biotechnology because of the cumulative and pyramidal structure of innovation.

In this paper we examine how a patent pool (which is an *ex ante* agreement) can rectify the lack of developer incentives to invest in an application when basic innovators cannot develop follow-up applications. We investigate whether broad basic patents are necessary in order to provide enough incentive to basic innovators, as is the case in the Green and Scotchmer (1995) model. Further, we wonder what kind of pool will emerge. In other words, are patents more likely to be broad or narrow in a patent pool? We consider a model in which there are two patentholders of basic innovations that are mainly research tools, whose market values are null, but they permit a third firm to develop an application. In this setting we show that patent pools are more likely to be formed either with patents of very different breadth or, on the contrary, with similarly broad patents.

In 2001 several companies (GE Healthcare former Amersham Biosciences, BioImage A/S and Invitrogen IP Holdings former Aurora Biosciences Corporation) and Colombia University agreed to pool several of their patents on green fluorescent protein (GFP). This is a fluorescent reporter molecule used in drug discovery to create a detailed picture of how potential drugs affect

[3]This survey has been conducted by Jon Merz and Mildred Cho, bioethicists at the University of Pennsylvania, and has been reported by Thompson, *Washington Monthly*, April 2001.

the function of protein. The patent pool contains several US patents, as well as European and Japanese patents. "All users of GFP are required to obtain a license to use the technology prior to starting research work" (GE Healthcare conditions for licensing).[4] Therefore, one can consider a patent pool as an *ex ante* agreement offered to any potential developers. The application areas include research in cell biology and pharmaceutical screening. Using Lerner's proxy of the scope of patent (i.e., the four-digit of the international patent classes), we find that the patents included in the pool tend to be broad. Indeed, according to Lerner's analysis (1994), biotechnology patents have, on average, 1.68 number of four-digit IPCs. Among the eleven patents that are in the pool, if we put together those that are continuations of others (two patents, each with two continuations), most have more than two four-digit IPCs. In fact, only one of them has one four-digit IPC. This seems to be consistent with one of our results that states that pools are more likely to be formed with broad patents (see Table 1 that summarizes the information about this existing patent pool).

Our analysis is related to the two streams of literature mentioned above: the literature on sequential innovation and more particularly the paper by Green and Scotchmer (1995), and the more recent literature on patent pools.

In a model with one patentholder on a basic innovation and one potential innovator to develop the application, Green and Scotchmer (1995) show that an *ex ante* agreement should be allowed in order to insure that investment in the second innovation will be undertaken. When there is no uncertainty about the value of the follow-up innovation, the best policy consists in giving a broad patent to the first innovator and the *ex ante* licensing improves social welfare whatever

[4] See the web site http://www.gehealthcare.com.

the patent breadth.[5] However, if the developers' costs are private knowledge, patentholders do not necessarily offer *ex ante* licensing (Bessen, 2004). We built up on the model of Green and Scotchmer (1995) to investigate patent pools. We explicitly introduce patent breadth, and we extend their analysis to two basic patents that can be pooled in an *ex ante* agreement in a model where there is common knowledge about costs.

Patent pools are viewed as a possible solution for reducing additional transaction costs incurred in navigating the patent thicket (Shapiro, 2001) or the anticommon problem (Heller and Eisenberg, 1998). They can also enhance efficiency by eliminating the complement problem (Shapiro, 2001), and may benefit society (Gilbert, 2004; Lerner and Tirole, 2004; Gilbert and Katz, forthcoming). Following Cournot analysis, Shapiro (2001) shows that a package of licenses for basic innovations neither harms consumers nor the firms themselves, as long as the royalty rates are low.

The major benefits of patent pools are that they eliminate staking licensing, reduce licensing transaction costs, reduce patent litigation and allow for the exchange of information. However, a patent pool can have anticompetitive effects. Antitrust authorities have been consistently more suspicious of a pool of substitutable patents than of a pool of complementary patents. If patents are perfect complements, a pool eliminates the double marginalization (Shapiro, 2001). If they are perfect substitutes, a pool eliminates competitors. However, patents are rarely perfect complements or perfect substitutes. In this context, Lerner and Tirole (2004) study a model of

[5] If there is competition at the level of development, Scotchmer (1996) shows that patents on second generation products (when they infringe on the first innovation) are not necessary to encourage their development, and the patentholder of the basic innovation collects a larger share of the profit if second generation products are not patentable. On the other hand, if competition can take place at both research and development stages, and if both stages can be done by the same firm, Denicolo (2000) shows that weak forward protection can be preferable.

pool formation and pricing and show that a pool can increase or decrease the price, depending on the internal or external competition. Further, large pools are more likely to allow individual licensing, centralize control of litigation and to license to third party (Lerner, Strojwas and Tirole, 2003). In our model, we consider that a patent pool is an *ex ante* agreement where patents are complements as both innovations are needed to develop the application. In this setting, we wonder what breadths of patents are more likely to be pooled together.

The paper is organized as follows. In section 2 we present a benchmark model, based on the Green and Scotchmer (1995) model, in which one basic innovator holds a patent. In section 3, we consider that two basic innovations are owned by two different patentholders and we determine the composition of the patent pool. Section 4 concludes.

2 Benchmark Case: One Basic Innovator

We consider a modified version of the Green and Scotchmer (1995) model (hereafter GS), in which only one initial innovator, firm 1, holds a patent. The associated (sunk) cost for discovering the basic innovation is c. This protected innovation has no value by itself, but it is necessary to develop an application. For instance, it could be a gene that may be useful in the development of a certain medicine.[6]

A second generation of product (an application that uses the patented innovation) has a monopoly value v and cost c_a of development. If it infringes, the application can only be introduced on the market if an (*ex ante* or *ex post*) agreement has been reached with the

[6] For instance, a combination of several research tools (the PCR enzyme for replicating DNA, technologies for inserting foreign genes into germplasms, technologies for making those genes produce proteins,...) has been used to develop a version of BT corn, i.e., corn seeds that code for and "express" (i.e., produce protein for) a particular kind of pest resistance.

patentholder, and thus, its value is v, to be shared with the initial innovator. If the application does not infringe upon the patented innovations, the value v is for the developer alone. There is no uncertainty concerning the future value of the application.[7]

The scope of protection (i.e., breadth) that the initial innovator obtains for his innovation can be narrow or broad. In the case of a patent of infinite breadth, the application will always infringe upon the patented basic innovation. On the contrary, if the breadth of patent is null, the application never infringes. Therefore, the breadth of a patent is related to the *ex ante* probability of infringing. Based on that observation, we define the breadth as being exactly the probability of infringing. Hence, with probability $b \in [0, 1]$ the application infringes upon the patent, and with probability $(1 - b)$ it does not.[8]

At best, if the first innovator of the basic innovation were to develop the application as well, he would invest in the application if $v - c_a > 0$.

However, the initial innovator may be unable to develop the application if, for instance, he specializes in fundamental research rather than in development. In this setting, the application must be developed by another firm that does not hold the basic innovation, and we assume that the application can be developed by only one firm.

Consider that only one innovator, namely firm A, can develop the application. Following GS (1995) we assume that parties will achieve *ex post* efficiency. In other words, in absence of any *ex ante* agreement, the developer and the basic innovator must agree on an *ex post* licensing if the application infringes on the basic patent. Without such an agreement, the application cannot be developed. So the patentholder gets $-c$ and the developer $-c_a$ if he has decided to invest.

[7] We consider a very simple model where there is no uncertainty. A more realistic approach, and more complicated, should take into account the fact that the value of the application is uncertain.

[8] Broad biotechnology patents are more likely to be litigated (Lerner, 1994).

The developer can also decide not to invest in the application, and thus, the patentholder still has the same fixed cost to incur and the developer has a null payoff. If the developer invests and the application infringes upon the patent, both firms reach an *ex post* agreement, and therefore, firm 1 gets $-c + Kv$ and firm A gets $-c_a + (1 - K)v$, where K represents the fraction of the gain that goes to the first innovator. If the infringement always occurs ($b = 1$), the developer invests only if $-c_a + (1 - K)v > 0$. The investment in the application will not be undertaken as often as if the same unique firm were to do all of the research and development. So here the developer does not invest enough.

If the application does not infringe upon the basic innovation ($b = 0$), the developer can exploit his innovation without having to pay for the use of the initial patent. The first innovator gets a payoff of $-c$ and the developer enjoys the total benefit from the application $-c_a + v$.

However, *ex ante*, nobody knows whether the application will infringe or not, and therefore, in order to decide to invest, the developer must compare his expected payoff from investing, i.e., $b(-c_a + (1 - K)v) + (1 - b)(-c_a + v) = -c_a + (1 - bK)v$ to 0. He will invest only if $-c_a + (1 - bK)v > 0$, which is clearly even worse than when they all know whether the application infringes or not.

As we are mainly interested in looking at the case where there is a lack of incentive to do research for the application if there is infringement, we restraint our analysis to certain values of the parameters. We assume that the value of the second generation product v is such that

$$v - c_a - c \geq 0 \tag{1}$$

$$v(1 - K) - c_a < 0 \tag{2}$$

$$Kv - c > 0 \tag{3}$$

Equation (1) states that all of the research would have been undertaken by the initial innovator, had he been able to do so. In other words, the innovation is worthwhile. The second assumption (2) implies that if the infringement occurs, no *ex post* agreement can be reached. And finally, the third assumption (3) insures that the basic innovator undertakes the basic research as long as he can get a sufficient market share in the *ex post* agreement.

In order to solve the under-investment problem, we follow GS (1995) and we assume that the firms can sign an *ex ante* agreement. Before the investment is undertaken by the developer, both firms can agree on *ex ante* licensing. In GS (1995), firms are engaged in a cooperative simultaneous bargaining game. Each of them receives his threat point profit plus one-half of the bargaining surplus. Thus, for each threat-point considered, the firms will get a certain profit that must be at least equal to what they will earn without it.

Here we depart from the GS model, and assume that first the patentholder decides to offer an *ex ante* agreement to the developer, who decides whether or not to accept it (a "take-it-or-leave-it" offer). The payoff of the patentholder becomes $-c + k(v - c_a)$, and the developer, $(1 - k)(v - c_a)$, where k is at the discretion of the patentholder. The first-mover advantage that results from this sequential bargaining will manifestly push the patentholder to make an offer with k as large as possible ($k = 1 - \varepsilon$, with ε very small).

The possibility of having an *ex ante* agreement restores the incentive to invest. Indeed, the investment will take place if $(1 - k)(v - c_a) > 0$. Thus, as long as $k > 0$, the investment will be undertaken if $v - c_a > 0$, even if $-c_a + (1 - bK)v < 0$. In GS (1995), when the threat-point profit is $-c$ for the patentholder and 0 for the developer, as is the case when the developer does not invest without an *ex ante* agreement, the *ex ante* agreement payoffs become $-c+(v-c_a)/2$ for the patentholder and $(v - c_a)/2$ for the developer. In their formulation, $k = 1/2$, as both firms simultaneously agree on a share of profits, and $b = 1$ or $b = 0$.

Without an *ex ante* agreement, the developer will decide to invest if $-c_a + (1 - bK)v > 0$. If this inequality does not hold, the *ex ante* agreement will be preferred as long as $(1-k)(v-c_a) > 0$, and this does not depend on the breadth. However, if the previous inequality holds, the patent breadth plays a crucial role.

If the patent is so narrow that there is no infringement ($b = 0$), the developer will accept the *ex ante* agreement only if $(1 - k)(v - c_a) > v - c_a$. This last inequality never holds, and hence there will be no *ex ante* agreement. Or, in other terms, the developer gains more when his application does not infringe than when it does. This result is similar to one of GS (1995). From it, they conclude that in order to reduce the payoff of the developer, the best patent breadth must be infinite.

For any positive value of the breadth ($0 < b \leq 1$), if an *ex ante* agreement can be reached, the developer will invest whenever an *ex ante* agreement has been offered, but only for $b < (v - c_a)/Kv$ if the patentholder does not offer such an agreement. Further, the developer will accept an *ex ante* agreement as long as $b > \min[k(v - c_a)/Kv, (v - c_a)/Kv]$. However, in choosing between an *ex ante* agreement or *ex post* efficiency, the patentholder never offers an *ex ante* agreement as long as $b > [k(v - c_a)/Kv, (v - c_a)/Kv]$. Therefore, for $b < (v - c_a)/Kv$, *ex post* efficiency will be reached, whereas for $b \geq (v - c_a)/Kv$, an *ex ante* agreement will be reached. We summarize this first result due to Green and Scotchmer (1995).

Proposition 1 *(Incentive to develop) If there is only one basic innovator, ex ante agreement restores the incentive to develop an application.*

Nevertheless, *ex ante*, the patentholder needs to have enough incentive to invest in the basic innovation. In absence of an *ex ante* agreement, firm 1 will undertake basic research only if

$b \geq c/Kv$. In presence of an *ex ante* agreement, it will undertake basic research if $k \geq c/(v - c_a)$. We can, thus, posit the following result.

Proposition 2 *(basic research) Under assumptions (1)-(3), firm 1 invests ex ante in basic research only if the patent protection is not too narrow (i.e., $b \geq c/Kv$) and the market share he gets in case of an ex ante agreement is large enough (i.e., $k \geq c/(v - c_a)$).*

Once firm 1 has enough incentive to invest in basic research, we can summarize whether an *ex ante* or *ex post* agreement will take place at the equilibrium in the following proposition.

Proposition 3 *(ex ante versus ex post agreements) Under assumptions (1)-(3), and if there is investment in basic research (i.e., $b \geq c/Kv$ and $k \geq c/(v - c_a)$),*

i. for smaller probabilities of infringement, i.e., $b < (v - c_a)/Kv$, the equilibrium is such that there is only ex post agreement.

ii. for larger probabilities of infringement, i.e., $b \geq (v - c_a)/Kv$, the equilibrium is such that there is only ex ante agreement.

For intermediate values of the patent breadth ($b \in [c/Kv, (v - c_a)/Kv]$), the Nash perfect equilibrium is such that the patentholder does not offer an *ex ante* agreement, and the developer invests. If infringement occurs, there is *ex post* efficiency (point *i.*). For a broad patent protection ($b \in [(v - c_a)/Kv, 1]$), the Nash perfect equilibrium is such that the patentholder offers an *ex ante* agreement that the developer accepts (point *ii.*).

If the objective of the government is to minimize the monopoly power of the innovator without reducing the incentive to do either fundamental or applied research, the best policy could be to set $b^* = c/Kv + \varepsilon$, as long as $k \geq c/(v - c_a)$. With such patent protection, at the equilibrium only *ex post* agreement will occur.

There is an implicit trade-off between length and breadth. Indeed, if the value of the application v depends on the duration of the patent, and if we assume that the longer the patent, the higher the value of the application, long patents do not need to be broad. There is a trade-off between long and narrow patents, and short and broader patents. Furthermore, as $\partial b^*/\partial K < 0$, the higher the market share of the profit that goes to the basic innovator, the narrower should be the patent protection.

If the patent protection is broader (i.e., $b \geq (v - c_a)/Kv$), the *ex ante* agreement restores the incentive to develop the application. However, the patent protection does not need to be very broad (i.e., $b = 1$) to give enough incentive to the basic innovator. If $b = (v - c_a)/Kv$, the higher the K, the lower the b. On the other hand, $\partial b/\partial v > 0$, and thus the higher the value of the application, the larger the patent breadth.

The sequential bargaining game introduces a decision stage, and the bargaining is no longer the equilibrium solution. Nevertheless, we find, as in the GS (1995)'s model, that *ex ante* agreement can restore the decision of the developer to invest, and that the first patentholder cannot capture all of the surplus.

We now consider that two basic patents are held by two innovators.

3 Two Basic Innovators and Patent Pool

Consider now that instead of having one initial innovator, we have two initial innovators, called firms 1 and 2, and each of them holds a patent on a basic innovation. They have incurred costs c_1 and c_2 to make these discoveries. We continue to assume that each basic innovation has no value by itself, but is indispensable in developing an application. In other words, even if their value is null, their value-added quality is very important to the applications' development. The follow-up innovation (or application) still has a value of v once it has been developed at cost c_a by another firm. The application cannot exist without the two basic discoveries. As before only one innovator can develop the application.

If the application does not infringe on the two previous patents, then its value is simply v, as the developer can freely use both basic innovations without having to pay royalties to their holders.

We first consider the two polar cases where the application does and does not infringe on the basic innovations. Then we introduce the breadth of the patents.

3.1 Infringement or No Infringement

Without *ex ante* agreement, the developer has to decide whether to invest or not. If he does not invest, each patentholder receives $-c_i$, where $i = 1, 2$ and the developer has a null payoff. If he decides to invest and the application does not infringe on the two basic patents, the payoffs are $-c_i$ for each $i = 1, 2$ and $v - c_a$ for the developer. In case of infringement, we assume that the application infringes on both patents. As we assume that there is *ex post* efficiency, the developer and both patentholders agree on *ex post* licensing. This leaves payoffs of $-c_i + K_i^e v$ to each patentholder $i = 1, 2$ and $-c_a + (1 - K_1^e - K_2^e)v$ to the developer, where K_i^e is the fraction of payoff that goes to each patentholder. In absence of any *ex ante* agreement, the developer will not invest if $-c_a + (1 - K_1^e - K_2^e)v < 0$ even if $-c_a + v > 0$. There is therefore, the same under-investment problem with two patentholders. However, if *ex ante* agreements can be reached, this problem can be solved.

We assume that both patentholders decide simultaneously whether or not to pool their patents. If they both agree on a patent pool of their two patents, they can propose an *ex* *ante* agreement to the developer. Then the developer may decide to refuse or accept it. If one patentholder decides not to pool, we assume that the patentholder does not want to offer any kind of *ex ante* agreement to the developer. Then, if one of them agrees to pool and the other refuses, no pool will be proposed, but the patentholder who wanted to be part of a pool offers an *ex ante* agreement to the developer.

It can be the case that both patentholders propose an *ex ante* agreement (in a patent pool), none propose it, or eventually just one propose it. If both of them propose an agreement and the developer accepts it, they will receive $-c_i + k_i^p(v - c_a)$ for $i = 1, 2$, with $(1 - k_1^p - k_2^p)(v - c_a)$ for the developer.[9] If only one of the patentholders proposes an *ex ante* agreement to the developer (as he was the only one willing to form a pool), the application can still infringe on the other patent. If it does, *ex post* licensing is needed to bring about the application. In this case, the patentholder that refuses the *ex ante* agreement, let us say j, will bargain over the totality of the gain from the application, namely v. Thus, the payoff of j will be $-c_j + K_j v$ for $j = 1, 2$ and $j \neq i$. The surplus over which firm i and the developer will *ex ante* bargain is thus $(1 - K_j)v - c_a$. Therefore, the patentholder i gets $-c_i + k_i((1 - K_j)v - c_a)$ and the developer gets $(1 - k_i)((1 - K_j)v - c_a)$.

We now consider that each patent has a different breadth, and thus, we define b_i as the breadth for the patent that belongs to firm i for $i = 1, 2$. We do not define *a priori* which patent is broader than the other, and as before, we assume that $b_i \in (0, 1)$ for $i = 1, 2$.

If the application does not infringe ($b_1 = b_2 = 0$), then depending upon with whom the developer has an *ex ante* agreement, the payoffs are $-c_j$ for the patentholder that does not

[9] As patentholders decide to propose a pool of patents, they can choose k^p such that each patentholder gets $-c_i + \frac{1}{2}k^p(v - c_a)$, where k^p represents the fraction that goes to the pool, and $(1 - k^p)(v - c_a)$ to the developer.

have an *ex ante* agreement, $-c_i + k_i(v - c_a)$ for the patentholder that proposes such an *ex ante* agreement, and $(1 - k_i)(v - c_a)$ for the developer.

As before, in the case where the application infringes ($b_1 = b_2 = 1$), at best, if both patentholders propose an *ex ante* agreement, the developer can earn $(1-k_1^p-k_2^p)(v-c_a)$. Thus, as long as this payoff is positive, the application will be brought about. But if only one patentholder decides to propose an *ex ante* agreement, the developer will get $(1 - k_i)((1 - K_j)v - c_a)$, and therefore, the investment will be undertaken only if $(1 - K_j)v - c_a > 0$, i.e., less often than in the case with only one patentholder of basic innovations.

As the patentholders choose simultaneously whether or not to propose a pool of basic patents to the developer (and thus, whether to propose an *ex ante* agreement or not), we can find the Nash equilibria that solve the patent pool game. Because we are mainly interested in knowing how firms will behave when the investment is not undertaken in the case of no *ex ante* agreement, we assume that the value of the second generation product v is such that

$$v(1 - K_1^e - K_2^e) - c_a < 0 \tag{4}$$

$$v(1 - K_i) - c_a < 0 \tag{5}$$

$$K_i v - c_i > 0 \tag{6}$$

We first consider the case in which the application infringes on the two basic patents. If patentholder i believes that j will choose to propose a pool, j is better off choosing not be part of the pool offer, as he will earn $-c_i + k_i v$, compared with $-c_i + k_i^p(v - c_a)$ if he proposes an *ex ante* agreement. If he anticipates that j will not offer an *ex ante* agreement, i will decide to offer it as $-c_i + k_i((1 - K_j)v - c_a) > -c_i$. We thus find two symmetric Nash equilibria. These results hold as long as $(1 - K_j)v - c_a > 0$. If $(1 - K_j)v - c_a < 0$, the two patentholders have an incentive to pool their patents as they both compare $-c_i + k_i^p(v - c_a)$ to $-c_i$.

Proposition 4 *(patent pool and infringement) Under assumptions (1)-(6), if the application infringes on both patents and $k \geq c_i/(v - c_a)$, there exists a Nash equilibrium in which the two patentholders decide to pool. The developer accepts the ex ante agreement.*

If assumption (5) is relaxed, there exists two symmetric Nash equilibria. Either patentholder i proposes an *ex ante* agreement and j does not or, conversely, patentholder i does not proposes an *ex ante* agreement and j does. The developer accepts the agreement. The patentholders are better off if they do not simultaneously propose an *ex ante* agreement when the application does infringe on the two basic patents. The reason is simply that neither of them want to be the first to propose an agreement, but they prefer that someone proposes the agreement over having no agreement. If they were to make their decisions sequentially, there would be a first mover advantage. These equilibria preclude the developer to gain $(1 - k_1^p - k_2^p)(v - c_a)$ and he can only gain $(1 - k_i)((1 - K_j)v - c_a)$. Thus, the developer gains less without the pool.

If assumption (4) no longer holds, none of the basic innovators choose an *ex ante* agreement; thus, there is *ex post* efficiency.

Nevertheless, if $(1 - K_j)v - c_a < 0$ a patent pool is the better solution, as otherwise the development will not be undertaken.

We now consider the case in which the application does not infringe upon the two patents ($b_1 = b_2 = 0$). If there is an *ex ante* agreement with one of the patentholders, the payoffs are $-c_j$ for the patentholder who has no *ex ante* agreement, $-c_i + k_i(v - c_a)$ for the patentholder in the *ex ante* agreement, and $(1 - k_i)(v - c_a)$ for the developer.

We determine the Nash equilibrium in this setting. If one patentholder believes that the other will propose an *ex ante* agreement, he will also choose an *ex ante* agreement, as he compares $-c_i + k_i(v - c_a)$ to $-c_i$. If he anticipates that the other patentholder does not have such agreement, he proposes an *ex ante* agreement again, as $-c_i + k_i(v - c_a) > -c_i$. Thus, an *ex ante* agreement is a dominant strategy in case of non infringement.

Proposition 5 *(patent pool and non-infringement) If the application never infringes on either patent, there exists a unique Nash equilibrium in which the two patentholders decide to pool. The developer refuses it, and thus, ex post efficiency is achieved.*

When the two patentholders decide to propose an *ex ante* agreement, the investment will be undertaken if $(1 - k_1^p - k_2^p)(v - c_a) > 0$. That is, if $k_1^p + k_2^p < 1$, the application will be brought about if $v - c_a > 0$.

3.2 Breadth of Patents

Consider now that the breadth defines the probability of infringing, and recall that b_1 is the breadth of the patent that belongs to firm 1 and b_2 is the breadth of the patent that belongs to firm 2.

Without *ex ante* agreement, if the developer does not invest, each patentholder receives $-c_i$, where $i = 1, 2$ and the developer has a null payoff. If he decides to invest, he gets $-c_a + b_1 b_2(1 - K_1^e - K_2^e)v + (1 - b_1)b_2(1 - K_2)v + b_1(1 - b_2)(1 - K_1)v + (1 - b_1)(1 - b_2)v$ and each patentholder gets $b_i b_j K_i^e v + (1 - b_j)b_i K_i v - c_i$ for $i = 1, 2$. Thus, the developer will invest only if $v(1 - b_1 K_1 - b_2 K_2 + b_1 b_2 \Delta K) - c_a > 0$, where $\Delta K = K_1 - K_1^e + K_2 - K_2^e$. Therefore, as long as $b_2 \leq f_1(b_1) \equiv ((v - c_a)/v - b_1 K_1)/(K_2 - b_1 \Delta K)$. Let us define $\Gamma = \{(b_1, b_2)/b_2 \leq f_1(b_1)\}$.

With *ex ante* agreement, and if both patentholders propose an agreement and the developer accepts it, they will receive $-c_i + k_i^p(v - c_a)$ for $i = 1, 2$ and $(1 - k_1^p - k_2^p)(v - c_a)$ for the developer. If only one of the patentholders proposes an *ex ante* agreement to the developer, the application can still infringe on the other patent. If it does infringe, an *ex post* licensing is needed to bring about the application. Thus, the patentholder who refuses the *ex ante* agreement, let us say j, will bargain over the totality of the gain from the application, namely v. Hence, the payoff of j will be $-c_j + b_j K_j v$ for $j = 1, 2$ and $j \neq i$. The surplus over which firm i and the developer will *ex ante* bargain is thus $(1 - b_j K_j)v - c_a$. Therefore, patentholder i gets $-c_i + k_i((1 - b_j K_j)v - c_a)$ and the developer gets $(1 - k_i)((1 - b_j K_j)v - c_a)$.

As before, at best, if both patentholders propose an *ex ante* agreement, the developer can earn $(1 - k_1^p - k_2^p)(v - c_a)$, and thus, as long as this is positive, the application will be brought about. But if only one patentholder decides to propose an *ex ante* agreement, the developer will get $(1 - k_i)((1 - b_j K_j)v - c_a)$, and thus, the investment will be undertaken only if $(1 - b_j K_j)v - c_a > 0$, i.e., less often than in the case with only one patentholder of basic innovations.

As the patentholders choose simultaneously whether or not to propose a pool of basic patents to the developer (and therefore, whether to propose an *ex ante* agreement or not), we can find the Nash equilibria that solve the patent pool game.

We find that patentholders form a patent pool when they have patents of very different breadths, or on the contrary, very broad patents. When both basic patents are very broad, the developer will decide to develop the application only under *ex ante* agreements. Therefore, the application will only be brought about if a pool of patents is formed. On the other hand, a patentholder who has a very narrow patent is tempted to offer an *ex ante* agreement, while a patentholder with a very broad patent is tempted to wait for an *ex post* agreement. However, the developer will not accept an *ex ante* agreement from the holder of the narrow patent. Therefore, the application will be developed only if a pool of patents is first introduced. See figure 1.

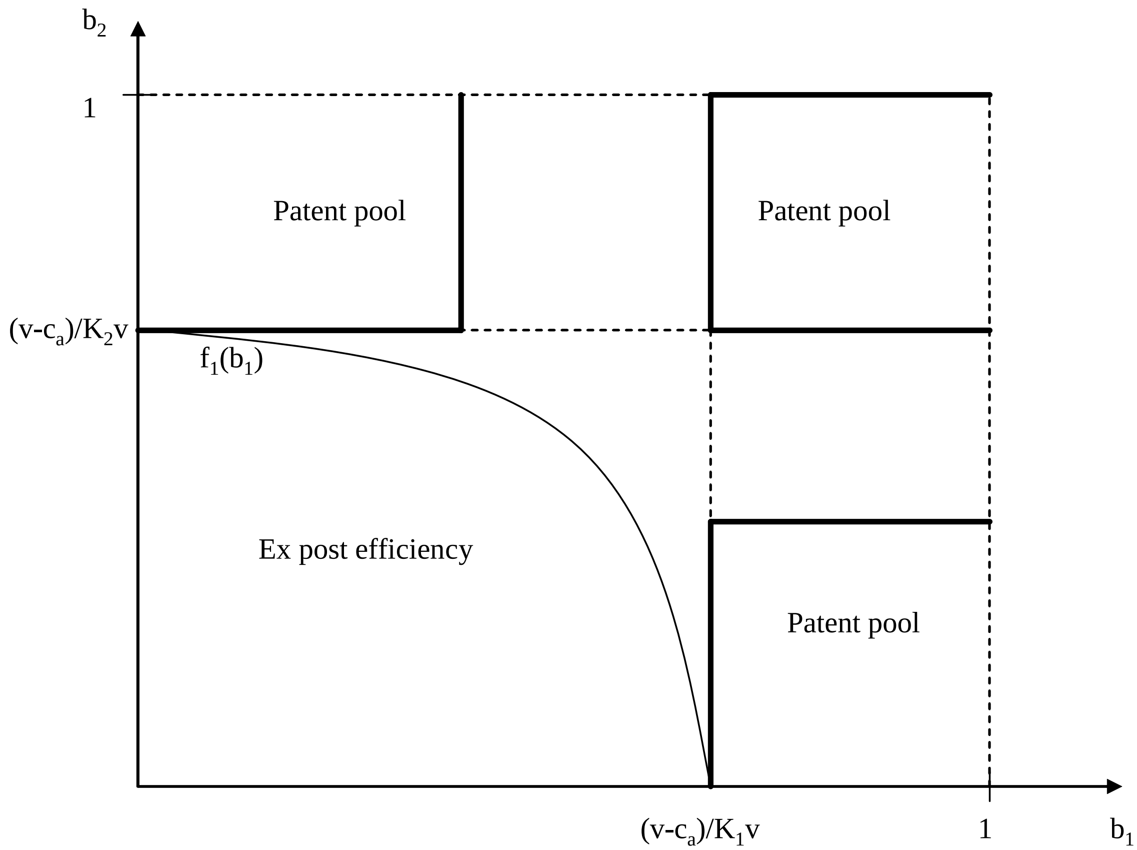

Figure 1: Patent pools

We summarize these findings in the following proposition.

Proposition 6 *(pool of patents) Under assumptions (4)-(6), a patent pool is formed if:*

1. *the two patents are very broad;*

2. *one patent is very broad and the other patent is very narrow.*

Proof. See appendix. ■

For all of the other configurations of breadth, *ex ante* or *ex post* agreements can be achieved, but no pool of patents will be offered. For very small breadth, $(b_1, b_2) \in \Gamma$, ex post efficiency is achieved at the equilibrium. For intermediate values of breadth, one firm offers an *ex ante* agreement and the other firm does not.

An alternative interpretation of b could be the ability of the innovators to litigate. Such ability arguably depends on the size and experience of the firms involved in the litigation process. Therefore asymmetric equilibria may reflect a pool composed of very different firms: an inexperienced firm (e.g., a start-up) that seeks some protection from a bigger and a more experienced firm.

However, basic innovators do not necessarily have the right incentive to *ex ante* invest in basic innovation.

For very narrow patents, when an *ex post* agreement can be reached ($(b_1, b_2) \in \Gamma$), basic innovators do not invest for $b_i \in [0, c_i/K_i v]$. Therefore, within this area, investment will occur only for $b_i > c_i/K_i v$.

For intermediate values of breadth, the basic innovator who proposes an *ex ante* agreement does not have enough incentive to invest. One of the basic innovators lacks the incentive for $b_i \in [(v - c_a)/K_j v - c_i/k_i K_j v, (v - c_a)/K_i v]$. In other words, if the breadth is too large within the considered interval, there will be no innovation, as one of the basic innovators lacks the incentive to develop the innovation that is needed to develop the application.

Therefore, *ex ante* agreement may not be enough to rectify incentives when two basic innovators must decide whether or not to pool their patents. Indeed, each of them has an incentive to free ride on the other. One of the basic innovators lets the other form an *ex ante* agreement with the developer, and then free rides in the case of infringement. The broader the patent, the higher the probability of free riding. However, if the patent is too broad, there is no investment.

Proposition 7 *(incentives to invest) If there are two basic innovators, ex ante agreement re-*

stores incentives to develop an application, but may reduce the ex ante incentive to invest in the basic innovations.

If we compare this result with the one basic innovator case, because of the free riding problem created by the possibility of letting the other basic innovator share the development cost, we have a situation of under-investment. Indeed, for the values of breadth where firms do not form a pool, but *ex ante* and *ex post* agreements occur, the incentive to develop the application is restored, but the incentive to do basic research is weakened. As a result, less innovation occurs.

4 Conclusion

Patents play an important role in many industries (e.g., biotechnology) and the existence of too many property rights on basic innovations impacts on follow-up applications. In a context where basic innovations have no value by themselves but are fundamental to development of an application, we show that basic innovators will tend to pool their patents when they have broad patents or when their patents are of very different breadth (one broad, one narrow). By doing so, they induce investment in applications that would not occur otherwise.

In this very simple setting, all of the variables are exogenous, and the only decisions are on whether to invest and whether to pool. We do not consider any strategic choice of breadth, but we rather investigate all of the possible pools that will emerge depending on the different breadths. We also consider the share of profit as given in the case of agreement.

Our analysis of pools relies on an *ex ante* agreement, motivated by the example given in the introduction, and on the fact that prior to doing research, innovators need to obtain a license in order to be able to develop an application.

The problem with such *ex ante* agreements is that they bring antitrust concerns. Should we allow initial patentholders to reach an *ex ante* agreement even though the application does not necessarily infringe on the initial patents? There exists evidence that the Department of Justice allows such *ex ante* agreement (patent pools) when patents are complements but are not substitutes or rivals (Shapiro, 2001).

One of our results suggests that the broader the patent protection of both patents, the more likely a pool of patents will emerge. Thus, one may wonder if the emergence of patent pools that has been observed during the recent years could be the result of a patent policy that allows for broad patents. However, we also find that patent pools can be composed of one broad and one narrow patent as well.

From an antitrust standpoint, such agreements are less problematic since they do not result in a strong barrier to entry but still foster and restore incentives to develop applications.

Appendix

Proof of Proposition 6

i) Investment decision for firm A

If no *ex ante* agreements are offered, firm A invests as long as $v(1-b_1K_1-b_2K_2+b_1b_2\Delta K)-c_a>0$ where $\Delta K=K_1-K_1^e+K_2-K_2^e>0$ or equivalently if $b_2\leq f_1(b_1)\equiv((v-c_a)/v-b_1K_1)/(K_2-b_1\Delta K)$ where $f_1(b_1)$ is a decreasing and concave function.

If the two basic innovators offer a pool, firm A always invests as $(v-c_a)(1-k_1^p-k_2^p)>0$. On the other hand if only firm 1 (respectively, firm 2) offers an *ex ante* agreement but not firm 2 (respectively, firm 1), firm A invests if $(1-k_1)((1-b_2K_2)v-c_a)>0$ (respectively, $(1-k_2)((1-b_1K_1)v-c_a)>0$), or equivalently if $b_2\leq(v-c_a)/K_2v$ (respectively, $b_1\leq(v-c_a)/K_1v$).

ii) Simultaneous decisions to pool or not for firms 1 and 2

We now define the Nash equilibria when *ex post* efficiency is not achieved, i.e., $b_2>f_1(b_1)$.

In absence of any *ex ante* agreement, firm A does not invest, and therefore the payoffs of firms 1 and 2 are $\Pi_1^{N,N}=-c_1$ and $\Pi_2^{N,N}=-c_2$. Let us represent a normal form of the game, where the payoffs of each firm depends on the decisions of each firm to pool or not.

1\2	*Pool*	*No Pool*
Pool	$\Pi_1^{P,P}$, $\Pi_2^{P,P}$	$\Pi_1^{P,N}$, $\Pi_2^{P,N}$
No Pool	$\Pi_1^{N,P}$, $\Pi_2^{N,P}$	$\Pi_1^{N,N}$, $\Pi_2^{N,N}$

We first define the Nash equilibrium when firm A invests when both firms decide to pool ($Pool$, $Pool$), and when only one of the basic innovator decides to pool, either ($Pool$, $No\ Pool$) or ($No\ Pool$, $Pool$) (i.e., for $b_i \leq (v - c_a)/K_i v$ for $i = 1, 2$). Therefore, the payoffs of firms 1 and 2 are

$$\Pi_1^{P,P} = -c_1 + k_1^p(v - c_a)$$
$$\Pi_2^{P,P} = -c_2 + k_2^p(v - c_a)$$

$$\Pi_1^{P,N} = -c_1 + k_1((1 - b_2K_2)v - c_a)$$
$$\Pi_2^{P,N} = -c_2 + b_2K_2v$$

$$\Pi_1^{N,P} = -c_1 + b_1K_1v$$
$$\Pi_2^{N,P} = -c_2 + k_2((1 - b_1K_1)v - c_a)$$

If firm 2 (respectively, firm 1) chooses not to pool, firm 1 (respectively, firm 2) always choose to pool as $\Pi_1^{P,N} > \Pi_1^{N,N}$ (respectively, $\Pi_2^{N,P} > \Pi_2^{N,N}$) is always satisfied.

A pool cannot be an equilibrium as both firms choose to pool for $b_i \leq k_i^p(v - c_a)/K_i v$ which is not possible.

Therefore there exists an equilibrium in which firm 1 (respectively, firm 2) chooses to pool whereas firm 2 (respectively, firm 1) does not pool for $b_1 \leq k_1^p(v - c_a)/K_1 v$ and $b_2 > k_2^p(v - c_a)/K_2 v$ (respectively, $b_2 \leq k_2^p(v - c_a)/K_2 v$ and $b_1 > k_1^p(v - c_a)/K_1 v$). For $b_1 > k_1^p(v - c_a)/K_1 v$ and $b_2 > k_2^p(v - c_a)/K_2 v$, there exist different equilibria: either firm 1 chooses to pool and not firm 2, or vice versa, firm 2 decides to pool and not firm 1.

Second, we define the Nash equilibrium when firm A invests when both firms decide to pool ($Pool$, $Pool$), and when only firm 1 decides to pool but not when firm 2 decides to pool, ($Pool$, *No Pool*) (i.e., for $b_1 \leq (v - c_a)/K_1 v$ and for $b_2 > (v - c_a)/K_2 v$). The payoffs of firms 1 and 2 are therefore identical to the previous ones except for

$$\Pi_1^{P,N} = -c_1$$

$$\Pi_2^{P,N} = -c_2$$

The Nash equilibrium is to (*Pool*, *Pool*) for $b_1 \leq k_1^p (v - c_a)/K_1 v$, and not to pool for firm 1 and pool for firm 2 (*No Pool*, *Pool*) otherwise.

Similarly for $b_1 > (v - c_a)/K_1 v$ and for $b_2 \leq (v - c_a)/K_2 v$, we find a Nash equilibrium in which both firms pool for $b_2 \leq k_2^p (v - c_a)/K_2 v$ and one in which firm 1 decides to pool and not firm 2 (*Pool*, *No Pool*).

Lastly, if firm A does only invest when a pool is offered, there is an unique equilibrium in which both firms decide to pool.

Hence, there exists a Nash equilibrium in which both firms decide to pool, i.e., (*Pool*, *Pool*) when

i. $b_1 \leq k_1^p (v - c_a)/K_1 v$ and $b_2 > (v - c_a)/K_2 v$ (i.e., patent 1 is narrow and patent 2 is broad)

ii. $b_2 \leq k_2^p (v - c_a)/K_2 v$ and $b_1 > (v - c_a)/K_1 v$ (i.e., patent 1 is broad and patent 2 is narrow)

iii. for $b_i > (v - c_a)/K_i v$ for $i = 1, 2$ (i.e., both patents are broad)

	# patents	year	assignee	related patents	Number of IPC
1	5,625,048	1997	Univ Cal		1
2	5,777,079	1998	Univ Cal	5,625,048	3
3	5,804,387	1998	Stanford		3
4	5,968,738	1999	Stanford		2
5	5,994,077	1999	Stanford	5,804,387	3
6	6,054,321	2000	Univ Cal	continuation	1
7	6,066,476	2000	Univ Cal	5,625,048	3
8	6,077,707	2000	Univ Cal	continuation	2
9	6,090,919	2000	Stanford	5,804,387	1
10	6,124,128	2000	U.Cal +Others		2
11	6,172,188	2001	Thastrup		3

Table 1: patent pool GFP

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