Patent Notice and Cumulative Innovation

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Cumulative innovation, the process of one innovator building on the efforts of earlier innovators is common and important. Economists who study innovation readily accept this assertion (as do I) even though it is hard to evaluate empirically. Because of the work of Suzanne Scotchmer and others, economists also recognize that cumulative innovation poses a serious challenge to those who try to design an optimal patent system. When one innovation builds on another, the patent system can be used to divide profits between two distinct innovators. But under normal conditions it cannot be designed to make both innovators full claimants on the flow of value created by their respective innovations.

Several articles have taken up the challenge of uncovering policy concerns that should help determine the division of profit beyond early and late innovators. Green and Scotchmer (1995) note that when different firms contribute innovations to a sequence, then total patent based profits will need to be higher than the profits required to induce a single firm to invest in the same sequence of innovations. Scotchmer and Green (1990) observe that a weak nonobviousness standard encourages disclosure that has social value because it speeds further development and reduces redundant innovation. O'Donoghue, Scotchmer and Thisse (1998) argue for broad and short patents in a quality ladder model because broad patents reduce duplicative investment. In contrast, Denicolò (2000) observes a weak nonobviousness standard and narrow breadth reduce possibly wasteful racing to achieve a first generation innovation.

Curiously, the lessons from these articles best apply to what are usually classified as discrete rather than cumulative technology. Drug discovery is a discrete technology in the sense that there are few inventions and few patents per product. The standard models of cumulative innovation apply well to problems like how to divide patent profits between the inventor of a new drug and follow-on innovators who find a new use or new formulation of the drug.

The models do not work very well for cumulative technologies like the information and communications technologies. Three simplifying assumptions in these models are more problematic for cumulative technologies (ICT) than they are for discrete technologies. First, the division of patent profits is often crucial in the pharmaceutical industry, but often not very important in ICT, because the total patent profits are small. See Cohen, Nelson and Walsh (2000); Bessen and Meurer (2008). Second, the models assume that there is value in the disclosure contained in the early patent, and that the early invention is essential to later innovation. In ICT independent invention and inadvertent patent infringement are common. Bessen and Meurer (2008). Third, the models emphasize ex ante licensing as an option for coordinating early and late stage innovation. But such coordination is impossible if the potential contracting parties cannot find each other. Cockburn and Henderson (2003) find that most firms do not engage in product clearance patent searches before they introduce a new product. Pharmaceutical firms, however, are religious about doing patent searches as different decision points in the innovation process.

My goal in this paper is to modify a standard model of cumulative innovation to better account for some of the factors that cause patents (especially outside pharmaceutical technology) to perform badly as property. Bessen and Meurer show that patents fail as property in the sense that they deliver small net rewards to innovators (even negative rewards), because they fail to communicate information about patent-based property boundaries to strangers. To lawyers this is known as failure of the notice function of property.

I. Cumulative Innovation, Hold-up, and Ex Ante Patent Licensing

In this paper I combine a model of cumulative innovation and patent licensing that follows Green and Scotchmer (1995) with a search model. The model has two players, a patent owner and an innovator. They hold symmetric information. In the first stage, the innovator conducts a search for a patented technology to incorporate into its innovation. The goal of the search is to find and license a patent that might be asserted against the innovator, and to reduce development costs by building on the patented technology held by the patent owner. Search is costly because the patent system does not provide perfect notice.

If the search is fruitful and reveals a relevant patent (I assume there is at most one), then the innovator has a chance to negotiate a license before sinking its development cost. Regardless, of whether an ex ante license is negotiated, the innovator then decides whether to develop the innovation. Lacking an ex ante license, the innovator is vulnerable to a patent lawsuit, and it may be forced to negotiate an ex post license following development.

If the search does not reveal a relevant patent, then the innovator can do nothing, or develop the innovation. I assume the development cost is (weakly) greater after a failed search. Development exposes the innovator to a possible patent lawsuit and it might negotiate an ex post license with the patent owner.

In this section, I will analyze the subgame that follows a search that uncovers a relevant patent. The next section analyzes the subgame that follows a fruitless search, and the entire game including search. Let V measure the value of the innovation. The cost of development is c, where $c \leq V$. Thus, the social planner always prefers development. If the firms go to trial they each bear the litigation cost L. The probability of victory by the innovator is α, thus, the patent owner is sure to win at trial if $\alpha = 0$. If the patent owner wins at trial, the remedy is an injunction; the innovator cannot profit from the innovation, which includes the patented technology, unless it gets permission from the patent owner. I will assume that the innovator can design around the patent and deploy an alternative innovation with value X, where $X \in [0, V]$. I assume that the design around alternative is not available to the innovator until after the patent claims are interpreted at trial, and the innovator can determine the boundaries of the patent claims. The value X is net of additional development costs.

Licensing does not occur if the patent owner lacks a credible threat of going to trial. The patent owner's expected profit is:

(1) $$\frac{1-\alpha}{2}(V-x)-L.$$

This profit expression arises because: the patent owner bears it own litigation cost L regardless of the trial outcome; the patent owner wins with probability $1-\alpha$; and following a win, the patent owner negotiates a post-trial license and equally splits the surplus achieved when the innovator deploys the original technology instead of inventing around the patent. If expression (1) is less than zero, then there is no license, the patent owner earns zero, and the innovator earns $V - c$. I will call this outcome *acquiescence*.

My assumption of symmetric information means that trial will not occur in equilibrium. Instead, it provides the threat point for ex post licensing (that is, a license after development, but before trial). If the expression in (1) is non-negative, then the threat point for the patent owner is given by (1), and the threat point for the innovator is: $\frac{1-\alpha}{2}(V+x)+\alpha V-c-L.$ The firms will negotiate a license to avoid the litigation costs. Assuming an equal split of the surplus, then the *ex post license* outcome gives the patent owner an expected profit of: $\frac{1-\alpha}{2}(V-x),$ and the innovator gets an expected profit of:

(2) $$\frac{1-\alpha}{2}(V+x)+\alpha V-c.$$

Green and Scotchmer observe that the innovator is subject to hold-up and may find that development is not profitable without an ex ante license. In particular, if expression (2) is less than zero, then the innovator will not develop the technology unless the patent owner agrees to bear some of the development cost.

The equilibrium outcome is *ex ante licensing* when the patent owner has a credible threat to sue, and the innovator has a credible threat to forego development. In other words, ex ante licensing requires expression (1) is non-negative and expression (2) is negative. The threat points for the negotiation of an ex ante license are zero for both firms. The surplus is $V-c$, which is divided equally so that each firm gets $(V-c)/2$ from an ex ante license.

Figure 1

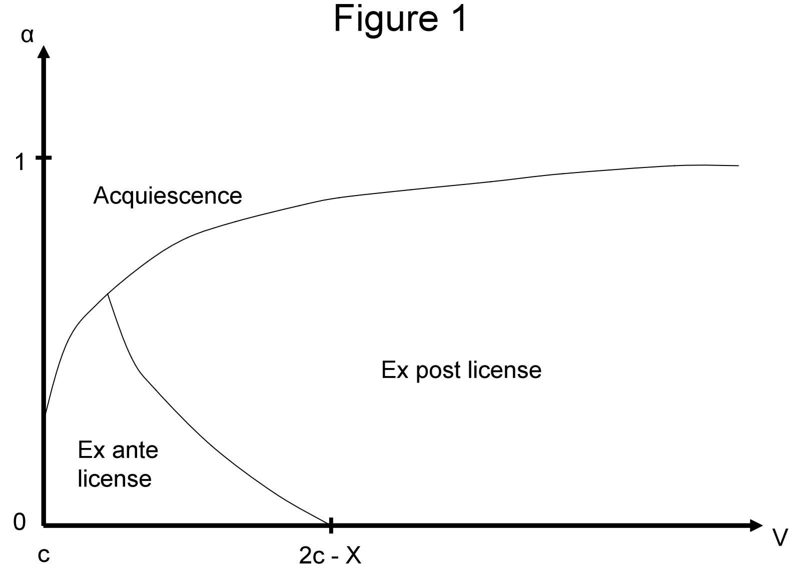

Figure 1 displays the set of (V, α) parameter values that correspond to different outcomes of the licensing subgame that occurs after a relevant patent is identified by the innovator's search. The figure is drawn on the assumption that $2L + X \leq c$. A relatively high development cost makes the region of ex ante licensing larger. If $2c \leq 2L + X$, then ex ante licensing is not an equilibrium outcome. The intermediate case is similar to the case displayed in Figure 1, except for values of V sufficiently close to c, the patent owner does not have a credible threat to sue even if victory is certain, in other words, even if $\alpha = 0$.

Remark 1. As noted by Green and Scotchmer, ex ante licensing has social value because it assures development of the innovation when its value exceeds development cost. Social value is realized only in the region of figure 1 labeled *ex ante licensing*. There is no social (or private) value to ex ante licensing for sufficiently large values of α , L, V, or X, because either the patent owner lacks a credible threat of a lawsuit to induce licensing, or because the innovator lacks a credible threat of foregoing development.

Remark 2. Ex ante licensing and the threat of hold-up also has implications for the division of profits. For certain parameter values, the patent owner makes more money if its patent is made weaker. This counterintuitive result arises because when the innovator has a credible threat to forego development, it shifts part of the development cost to the patent owner through the terms of the ex ante license. A small increase in α or X that changes expression (2) from negative to positive can shift the equilibrium outcome from ex ante licensing to ex post licensing, and raise the profit of the patent owner, because the innovator loses its credible threat to forego development.

II. Search, Development, and Patent Licensing

If the innovator conducts a fruitless search and decides to develop the innovation anyway, then it faces a potential dispute with the patent owner. For now, I will assume that the patent owner is sure to observe the innovation. I will also assume that the innovator knows the strength of the patent, that is, the values of α and X, before investing in development. Then the parties will negotiate an ex post license unless the patent owner lacks a credible threat of going to trial. If expression (1) is negative, then the patent owner acquiesces. If expression (1) is non-negative, then the parties agree to an ex post license yielding the same profits as those given in Section I.

Before I can analyze the development decision I need to specify the remaining features of the model. Rather than assuming the patent owner's technology is essential to the innovation, I assume that it reduces the development cost. Let $C \geq c$ be the development cost when the innovator has not located the relevant patented technology. The innovator commits to an investment of s on search. It knows that there is at most one patented technology available that is relevant to the innovation it is contemplating. The probability that the relevant patented technology exists is given by p. Conditional on the existence of a relevant patent the search technology finds it with probability $f(s)$. Thus, $pf(s)$ is the probability of finding a patent, $p[1-f(s)]$ is the probability of finding nothing even though a relevant patent exists, and $1-p$ is the probability that there is no relevant patent. Assume that $f(0) = 0, f' > 0 > f''$, and $f(s) < 1$ for all s.

Given this search technology I can now evaluate the profitability of a decision to develop the innovation after a fruitless search. If there is no relevant patent, then the innovator will capture $V - C$ from development. If there is a relevant patent that the innovator did not find and the patent owner has a credible threat to sue, then the profit from an ex post license is $\frac{1-\alpha}{2}(V+x)+\alpha V - C.$ Weighing these profits by the updated probabilities gives an expected profit of:

(3) $$\frac{1-p}{1-pf}V+\frac{p(1-f)}{1-pf}\left[\frac{1-\alpha}{2}(V+x)+\alpha V\right]-C.$$

If this expression is non-negative, then the innovator will develop the technology despite not finding a relevant patent. If the expression is negative, then the innovator will not develop the technology after a fruitless search. Alternatively, if the relevant patent is weak and the patent owner does not have a credible threat, then the profit is simply:

(4) $V - C.$

The equilibrium investment in search is driven by three considerations. First, a successful search reduces development cost by $C - c$, and thus, search increases with development cost savings. Second, search grows more attractive as the probability that there is a relevant patent grows. The relationship between equilibrium search and the hold-up problem is more complex. As noted in section I, an ex ante license can overcome a hold-up problem and assure development. This problem arises when $V \geq c$, but expression (2) is negative. Of course, an ex ante license is only possible if the innovator finds the relevant patent and its owner. Furthermore, a thorough, but failed search can give an innovator confidence to develop a technology when $V \geq C$. An intensive search that does not turn up a relevant patent reduces the ex post probability that there is a relevant patent and that hold-up will occur. In other words, expression (3) grows with search intensity, and increasing search can shift the value of the expression from negative to positive.

Proposition 1. Either the equilibrium search intensity, s*, solves $pG f'(s) = 1$, where G is the private gain to the innovator from successful search, or the equilibrium search intensity $s^* = \bar{s}$, where expression (3) equals zero at $\bar{s}$.

Proof. When the innovator chooses s it knows which of the three licensing outcomes from section I prevails. Let's consider the acquiescence outcome first. If $V \geq C$, then the innovator will develop regardless of the search outcome and the expected profit from search is: $V - pf(s)c - (1-p)f(s)C - s.$ The private gain from search is simply the development cost savings $G = C - c$, and the first order condition follows. If $V < C$, so that condition (4) is negative, then the innovator will only develop after successful search and the expected profit from search is: $V - pf(s)c - s.$ The private gain from search is the development surplus, $G = V - c$, and the first order condition follows.

Next, suppose that the parameter values are such that the ex post licensing outcome prevails after the innovator has identified the relevant patent owner. The expected profit function may have a kink because expression (3) can be negative for some values of s and positive for others. It is easy to show that expression (3) is increasing in s. It is possible that (3) is positive for all values of s, it possible that it is negative for all values of s, and it is possible that it is negative for $0 \leq s < \bar{s}$, and it is positive for $\bar{s} < s$. The expected profit from search when (3) is negative is: $pf(s)[\alpha V + (1-\alpha)\frac{V+X}{2} - c] - s.$ The expected profit from search when (3) is non-negative is: $p[\alpha V + (1-\alpha)\frac{V+X}{2}] - pf(s)c - p[1-f(s)]C + (1-p)(V-C) - s.$ Notice that these profits are equal when expression (3) is zero.

When (3) is always positive or always negative, then the first order condition in Proposition 1 applies with an appropriate definition of G that I will give in a moment. When (3) is negative for small values of s and positive for large values, then the first order condition will be satisfied at s^*, and it may also be satisfied at another local minimum. The first order condition must be satisfied at s^* because the slope of the expected profit function at $s = \bar{s}$ is smaller approaching from the left, than approaching from the right. Intuitively, the profit function may have two humps, but it must have at least one. The private gain from search if (3) is negative for all s, or when $0 \leq s^* < \bar{s}$, is $G = \alpha V + (1-\alpha)\frac{V+X}{2} - c.$ And the private gain from search if (3) is positive for all s, or when $\bar{s} < s^*$, is $G = C - c$.

Finally, suppose the parameter values are such that the ex ante licensing outcome prevails after the innovator has identified the relevant patent owner. The same three possibilities regarding expression (3) that applied with an ex post licensing outcome also apply with an ex ante licensing outcome. The situations differ because the slope of the expected profit function at $s = \bar{s}$ is smaller approaching from the right, than approaching from the left — the opposite from the analysis of the ex post licensing outcome. This means that it is possible when $s^* = \bar{s}$ that the slope of the profit function is positive when approaching from the left and negative when approaching from the right so that the first order condition is not satisfied at the optimum. Putting that case to the side, the first order condition in Proposition 1 will hold with the appropriate definition of *G*.

The expected profit from search when (3) is negative is: $pf(s)\frac{V-c}{2} - s.$ In this case the private gain from search is $G = \frac{V-c}{2}$. The expected profit from search when (3) is non-negative is: $pf(s)\frac{V-c}{2} + p[1-f(s)][\alpha V + (1-\alpha)\frac{V+X}{2} - C] + (1-p)(V-C) - s.$ In this case the private gain from search is $G = \frac{V-c}{2} - [\alpha V + (1-\alpha)\frac{V+X}{2} - C].$

To gain a better understanding of the equilibrium let's consider a special case. If the patented technology is unnecessary to the innovator, so that $C = c$, then there is no search given an acquiescence outcome. The patent owner does not have a credible threat to sue, thus, the only reason to search for the patent is to gain a development cost benefit. Next, notice that expression (3) is greater than or equal to expression (2) when the development costs are equal. Hence, if the ex post licensing outcome prevails given a fruitful search, development will occur following a fruitless search. This in turn means that the private gain from search $G = C - c = 0$, and there will be no search.

In contrast, positive equilibrium search may occur given the ex ante licensing outcome, even when $C = c$. If the innovator foregoes development following a fruitless search (expression (3) is negative given optimal search), then search is profitable because ex ante licensing overcomes the hold-up problem. If the innovator develops despite a fruitless search, search is still profitable because when search is successful, the patent owner will share some of its rents with the innovator in the ex ante license.

III. Comparison of Private and Social Incentives to Search

The U.S. government has a variety of policy instruments that it could use to reduce patent search costs. It could require publication of all U.S. patent applications. It could prohibit or limit claim language changes in continuing applications. It could limit the number of patent in force, by raising fees or standards of patentability. It could reward innovators that conduct product clearance searches, or at least it could reduce the penalties imposed on searchers through the operation of the willfulness doctrine (and possibly the inequitable conduct doctrine).

Before we attempt to formulate policy reforms that encourage search, we should ask whether current search levels are too low. Or perhaps the easier question: how do private incentives to search compare to social incentives? If the social planner were in charge of the search choice, but not the litigation, licensing, or development decisions, then the objective function when development always occurs would be:

(5) $pf(s)(V-c)+p[1-f(s)](V-C)+(1-p)(V-C)-s,$ and otherwise:

(6) $pf(s)(V-c)-s.$

<u>Proposition 2.</u> If a fruitful search yields an acquiescence outcome or an ex post licensing outcome in which expression (3) is non-negative, then the private and social incentives to search are the same. If the expression (3) is negative and a fruitful search yields an ex ante or ex post licensing outcome, then the innovator does too little search compared to the socially preferred amount. If fruitful search yields an ex ante licensing outcome in which expression (3) is non-negative, then the innovator does too much search compared to the socially preferred amount.

Proof. Looking back to the proof of Proposition 1 we see the private gains to search are $G = C - c$, when innovation occurs regardless of the search outcome and when the acquiescence or ex post licensing outcome prevails. This matches the social gain that is derived from (5). In words, the social planner derives a benefit from search when it reduces development cost. Because the entire benefit of reduced development cost is captured by the innovator, the social and private incentives are aligned.

In the acquiescence outcome in which the innovator does not invest in development given a fruitless search, the private gain $G = V - c$. This matches the social gain that is derived from (6).

In the cases in which a fruitless search leads to no development, and either ex ante or ex post licensing prevails, then there is too little search. Once again the social gain is $V - c$, but the private gain in the ex ante licensing case is only $G = \frac{V - c}{2}$, and in the ex post licensing case the private gain is $G = \alpha V + (1-\alpha)\frac{V + X}{2} - c$. The private gains are smaller in both cases (recall that $X \leq V$). Private search is too low because the innovator does not appropriate the full value of the innovation.

In the remaining case there is too much search. The innovator develops the innovation regardless of the search outcome. The innovator seeks both the benefit of reduced development cost, and also the enhanced bargaining power associated with an ex ante license. The social planner cares about the former but not the latter. The social gain from search is $C - c$, and the private gain is $G = \frac{V - c}{2} - [\alpha V + (1-\alpha)\frac{V + X}{2} - C]$. The fact that expression (2) is negative is sufficient to prove that the private gain is larger.

Proposition 2 is especially interesting when evaluated in the context of a stylized comparison between pharmaceutical and ICT innovation. If patent notice and patent protection are both strong for pharmaceutical technology we might associate the problem of over-searching with that technology. In terms of the model, if search is cheap and the equilibrium value of f is high, then expression (3) is more likely to be positive. If patent protection is strong and X is small compared to V, then (2) is more likely to be negative. If the opposite assumptions are appropriate for ICT, then we are more likely to see too little search.

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