Holdup and Licensing of Cumulative Innovations with Private Information

By James Bessen*

Abstract: When innovation is cumulative, early patentees can hold up later innovators. Under complete information, licensing before R&D avoids holdup. But when development costs are private information, *ex ante* licensing may only occur in regimes with sub-optimal patent policy.

Keywords: patents, licensing, innovation, intellectual property
JEL codes: K3, L5, O3

*Research on Innovation and Visiting Scholar, MIT Sloan School of Management.
Thanks to Bob Hunt, Mark Lemley and Rosemarie Ziedonis for helpful comments.

1. Introduction

The broadening of intellectual property rights over the last two decades has raised concerns about "holdup" for cumulative innovation. When innovation is sequential, an early patent holder has a potential claim against subsequent innovators. Anticipating the expected cost of such claims, a second innovator may choose to perform a sub-optimal level of R&D or, perhaps, not to invest in the innovation at all. The concern is that broader patent rights may increase the occurrence of holdup, reducing R&D incentives, thus slowing the pace of innovation.

However, firms may avoid this holdup by licensing *ex ante*. Green and Scotchmer (1995) present a model with symmetric information where the initial patent holder offers a license before the second firm sinks funds into R&D. This license avoids holdup and permits all socially desirable R&D investments to be made.

Based on the efficacy of such *ex ante* licenses, a strand of the patent literature argues in favor of broad (but short) patents that provide the strongest incentives to the initial innovator, confident that subsequent innovators will not be held up. This literature includes Kitch's "prospect theory" (1977) and Scotchmer's paper that asks whether subsequent innovations should be patentable at all (1996).[1]

However, the models in this literature suggest that much, if not *all*, patent licensing should occur *ex ante* in industries with cumulative innovation. Empirical evidence suggests otherwise. In a study of announced licensing deals and alliances, Anand and Khanna (2000) found that only 5% or 6% of such agreements occurred *ex ante* in SIC 35 and 36 (and some of these are joint development ventures). This includes the computer and electronics industries, which are known for cumulative innovation. Only in SIC 28, chemicals and pharmaceuticals, were a substantial portion of agreements *ex ante* (23%). Furthermore, major licensors in semiconductors, such as Texas Instruments and Hewlett Packard, do not include any special consideration of *ex ante* contracts in their licensing programs (Grindley and Teece, 1997).

The reason may be asymmetric information. Indeed, the concept of sequential innovation seems implicitly to assume the existence of private information. Holdup only arises when the second innovator is a *different firm* from the first innovator. But why doesn't the first innovator develop the second innovation? With its patent, the first firm has greater incentive to develop a second non-competing innovation because it has no need to pay royalties; it may also have information about the first innovation long before other firms. So if the first innovator had all

[1] Gallini and Scotchmer (2001) review this literature, and, although they recognize the assumption of effective licensing, they conclude "with some caution, we can extract from the literature a case for broad (and short) patents."

the information necessary to produce a non-competing second innovation, it would do so, and sequential innovation would not occur. Usually it is argued that sequential innovation occurs because the second firm possesses specialized information, such as expertise in a particular technology (see, for instance, Scotchmer (1991, p. 31)). But how, then, can the first firm know the *cost* of developing and applying that expertise? This seems unlikely. Moreover, the second innovator has strong reason *not* to reveal information. As in Gallini and Wright (1990), such information may allow the first firm to develop the technology *itself*.

This note modifies the Green and Scotchmer (1995) model to treat the second firm's development cost as private information.

2. Basic Model

Consider risk neutral firms A and B where firm A has a patent and firm B has developed a product that infringes this patent.[2] This describes a common situation where innovation is cumulative and patents have breadth or scope. Without loss of significant generality, I assume that the two firms do not compete with each other.

The interaction occurs in four possible stages:

1. Firm A chooses whether to invest c_A in R&D. If it does, firm A obtains a patent and realizes monopoly profits v_A on the resulting product.[3]
2. Firm A considers offering a binding *ex ante* license to firm B. If A chooses to offer such a license, I initially assume that the bargaining interaction occurs as a single offer from A. Below I extend the model to allow multiple offers with Coasian dynamics. B may or may not accept the offer.
3. Firm B chooses whether to invest c_B in R&D. If it does, then the monopoly profits on this product are v_B. Although v_B is common knowledge, only firm B knows c_B. Moreover, firm A cannot accurately infer c_B after the fact.[4] Firm A only knows that c_B is drawn from a sample distributed according to a cumulative function $F(\cdot)$,

---

2 Green and Scotchmer also consider the case where firm B does not infringe, but the firms license essentially for anti-competitive reasons. They also consider patent "breadth" such that some subsequent inventions may not infringe the initial patent. Note that under U.S. legal practice, improvements on an invention are only very rarely exempt from infringement (Lemley, 1997).

3 In this model I consider only the holdup associated with a single patent, ignoring strategic patent portfolio behavior.

4 For example, costs cannot be inferred by observing the firm's *ex post* reported R&D spending. If costs could be inferred, an *ex ante* contract could be written specifying the royalty payment as a function of reported R&D spending. But unless firm A can monitor all the actual costs and effort, moral hazard arises: B can inflate the reported R&D. This is especially true because the total cost of innovating typically include large costs of adopting and implementing new technology that are not included in the R&D budget.

conditional on $0 < c_B < v_B$ so that $F(0) = 0$ and $F(v_B) = 1$. Also, F is twice continuously differentiable, and log-concave.

4. If firm B does invest and if an *ex ante* agreement was not reached in stage 2, then the firms bargain *ex post*.

The outcome of this latter negotiation depends on the firms' "threat" options, including litigation and "inventing around." To capture the reduced form of this outcome, I assume that firm A captures a share, s, of the profits on B's product, so that the *ex post* royalty payment is

$$r_1(s) = s \cdot v_B . \tag{1}$$

Green and Scotchmer effectively assume $s = ½$, but here it varies, $0 < s \leq 1$, and it is, at least partially, a policy instrument (industry technical factors may also influence invent around costs). A higher value of s, all else equal, indicates a more "pro-patent" policy.

2.1 Holdup and *ex ante* Licensing

Note that if

$$r_1 > v_B - c_B > 0 \tag{2}$$

then firm B will not choose to invest in stage 3, even though the innovation is socially desirable. This constitutes "holdup" or "licensing failure." In Green and Scotchmer's model (1995), holdup can be avoided if firm A offers an *ex ante* license with royalty $r_0 \leq v_B - c_B$. In that model, since firm A knows the value of c_B, it will want to offer such an *ex ante* contract when (2) holds—this way it can obtain a positive royalty instead of zero profits on the second innovation.

Here, however, firm A does not have such information. Instead, firm A will want to propose an *ex ante* license that maximizes expected royalties. Under the initial assumption that A can commit to a single offer, the expected royalties given a royalty rate, r, are

$$x(r) = r\,F(v_B - r) . \tag{3}$$

Then the optimum *ex ante* royalty rate for A is

$$r_0 = \arg\max_r x(r), \qquad 0 < r_0 < v_B . \tag{4}$$

It is straightforward to show that since F is log-concave, a unique interior solution exists.

2.2 Licensing solution

But will B accept this *ex ante* contract? That depends on the alternative royalty obtained from *ex post* bargaining. If $r_1 > r_0$, then B will prefer the *ex ante* contract, accepting it as long as $c_B < v_B - r_0$. If $r_1 \le r_0$, firm B will, instead, refuse the *ex ante* offer, choosing to invest as long as $c_B < v_B - r_1$. The optimal licensing royalty is then

$$r^*(s) \equiv \min\left(r_1(s),\, r_0\right) \quad . \tag{5}$$

Note that this is function of *s*, the policy variable. Define $\tilde{s} \equiv r_0 / v_B$. Then straightforward calculation shows

Proposition 1. If $s > \tilde{s}$, all licensing occurs *ex ante*. If, instead, $s \le \tilde{s}$, all licensing occurs *ex post*.

The region $s > \tilde{s}$ can be thought of as a strong pro-patent policy regime; $s \le \tilde{s}$ is a weaker patent regime where inventing-around is feasible and/or the litigation is uncertain. This result can explain the pattern of licensing observed by Anand and Khanna: the chemical industries have high invent-around costs, patents deliver strong appropriability, and these industries also have the highest incidence of *ex ante* licensing (Levin et al. 1987, Cohen et al. 2000). On the other hand, machinery, computers and electronics industries have low invent-around costs, patents deliver low appropriability, and these industries do very little *ex ante* licensing.

3. Social Welfare

With private information about costs, *ex ante* licensing does not necessarily eliminate holdup—firm B will still not invest when offered a license such that $c_B > v_B - r_0 > v_B - r_1$. Social welfare involves a trade-off: if royalties are too high, then B may not invest, but if royalties are too low, then A may not invest in some socially desirable innovations. Firm A will only choose to invest initially when its profits plus expected royalties exceed costs, $v_A + x\left(r^*(s)\right) > c_A$.

To calculate social welfare, I assume that social surplus equals the monopoly profits, $v_A + v_B$, so that if both innovations are made, net social surplus is $v_A + v_B - c_A - c_B$. The social planner knows the value of each innovation, but only knows the distributions of the costs, $c_B \sim F(\cdot),\, c_A \sim G(\cdot)$. I consider both the case where the second innovation can be made without the first (technical independence) and also the case where the second innovation technically requires the first (technical dependence). Holdup occurs in both cases, but the latter situation places greater weight on the success of the first innovator. In that case, expected social welfare is

$$W(s) = \int_0^{v_A + x(r^*(s))} (v_A - c)\, dG(c) \; + \; G\big(v_A + x(r^*(s))\big) \cdot \int_0^{v_B - r^*(s)} (v_B - c)\, dF(c)\,. \qquad (6)$$

For the case of technical independence, the probability in front of the second integral is dropped.

Defining the optimal policy, $\hat{s} = \arg\max_s W(s)$, it can be shown

Proposition 2. Given non-degenerate distribution $F(\cdot)$, the optimal policy falls in the "weak" region, $\hat{s} < \tilde{s}$, where all licensing is *ex post*.

Outline of proof: Given (5), it must be that $\left.\frac{dW}{ds}\right|_{s>\tilde{s}} = 0$. Then, using the first order condition implied by (4) and the envelope theorem, calculation shows that (taking the derivative from the left), $\left.\frac{dW}{ds}\right|_{s=\tilde{s}} < 0$. From this it follows that $W(\tilde{s} - \varepsilon) > W(s_1),\ \forall s_1 > \tilde{s}$ for some small ε.■

4. Sequential Bargaining

The above analysis assumes that in *ex ante* bargaining, firm A can commit to a single offer. This might be the case if the second innovation were subject to rapid obsolescence or if there were many possible second round innovators. In this section, I consider the alternative where firm A can rapidly make many sequential offers.

This bargaining is similar to the much-studied example of the durable goods monopolist (Fudenberg and Tirole, 1991, Chapter 10). Firm A sells an *ex ante* license (at zero cost) to firm B, but doesn't know B's "consumption value," $v_B - c_B$. In these models of sequential bargaining, firm A makes a series of offers that serve to reveal firm B's private information.[5]

There is, however, one important difference: firm A can credibly commit to offering *no* license *ex ante*, waiting instead for *ex post* profits. Firm A will choose do avoid *ex ante* bargaining altogether when the *a priori* expected profits from bargaining, π, are less than the expected *ex post* royalties, $x(r_1(s))$. Since firm A will, in general, earn no more than the single-offer royalty under sequential bargaining,

[5] My model corresponds to the "no gap" case, which can have multiple perfect Bayesian equilibria.

Proposition 3. Under sequential bargaining, the domain over s for which firm A offers *ex ante* licensing will not increase relative to the single-offer case. Moreover,

a. If $\pi < x(r_1(s))$ for some values of s where $r_0 < r_1(s)$, then the domain decreases over which A offers *ex ante* licenses, and,

b. If, under rapid sequential offers, $\pi \to 0$, as in the Coase conjecture, then firm A will offer no *ex ante* licenses and the socially optimal policy will occur at $\hat{s}$ as above.

Remark. It is possible that under some equilibria, the socially optimal policy will occur under *ex ante* licensing. This, however, is clearly very sensitive to the choice of parameters.

5. Conclusion

When the development costs of second round innovators are private knowledge, patentholders do not necessarily offer *ex ante* licenses. Moreover, socially optimal patent policy may well result in a regime where *ex ante* licenses are not offered. The possibility of *ex ante* licensing does not eliminate the problem of holdup in cumulative innovation.

References

Anand, B. N. and T. Khanna, 2000, The Structure of Licensing Contracts Journal of Industrial Economics, 48:1, 103-135.

Cohen, W. M., R. R. Nelson, and J. P. Walsh, 2000, Protecting Their Intellectual Assets: Appropriability Conditions and why U.S. Manufacturing Firms Patent (or not), National Bureau of Economic Research Working Paper 7552.

Fudenberg, Drew and Jean Tirole, 1991. Game Theory (MIT Press, Cambridge, MA).

Gallini, N. and S. Scotchmer, 2001, Intellectual Property: When is it the Best Incentive System? in: A. Jaffe, J. Lerner, S. Stern, eds., Innovation Policy and the Economy, volume 2. (MIT Press, Cambridge, MA).

Gallini, N. and B. Wright, 1990, Technology Transfer under Asymmetric Information, RAND Journal of Economics, 21:1, 147-160.

Green, J. R. and S. Scotchmer, 1995, On the Division of Profit in Sequential Innovation, RAND Journal of Economics, 26:1, 20-33.

Grindley, P. C. and D. J. Teece, 1997, Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics, California Management Review, 29, 8-41.

Kitch, E. W, 1977, The Nature and Function of the Patent System, Journal of Law and Economics, 20, 265-290.

Lemley, M., 1997, The Economics of Improvement in Intellectual Property Law, Texas Law Review, 75, 989-1084.

Levin, R. C., A. K. Klevorick, R. R. Nelson, and S. G. Winter, 1987, Appropriating the Returns from Industrial Research and Development, Brooking Papers on Economic Activity, 3, 783-820.

Scotchmer, S., 1991, Standing on the Shoulders of Giants: Cumulative Research and the Patent Law, Journal of Economic Perspectives, 5:1, 29-41.

Scotchmer, S., 1996, Protecting Early Innovators: Should Second-Generation Products be Patentable? RAND Journal of Economics, 27:2, 322-331.