

SHOULD GOOD PATENTS COME IN SMALL PACKAGES? A Welfare Analysis of Intellectual Property Bundling

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Abstract

Intellectual property owners often hold the rights to several patents, each of which is essential to make or use a product. We compare the welfare properties of package licenses, under which a licensee pays the same fee regardless of the number of technologies licensed, with component licenses, under which each technology is licensed separately and there is no quantity discount. A central finding is that a long-term package license can induce incentives to invent around patents and invest in complementary assets that are closer to their socially optimal levels than are those induced by a long-term component license. We also identify settings in which a short-term license is a partial substitute for a package license and a prohibition on package licensing induces parties to adopt contracts that result in less efficient complementary investment because of hold-up.

Keywords: Intellectual property; Licensing; Asymmetric information; Research and development

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I. INTRODUCTION

It is common for an intellectual property owner to hold several patents covering technologies that are valuable only if used together. Although it would seem natural to offer the rights to use these patents under a single license, such “package licensing” has long been greeted with skepticism under antitrust policy.¹ Two common objections to package licensing are claims that the practice: (a) forces licensees to purchase intellectual property rights that they do not want or need, and (b) discourages attempts to innovate around specific patents or have specific patents declared invalid, not infringed, or unenforceable, because eliminating the need to license a single patent would not change the package price for the remaining patents in the bundle.²

The first argument against package licensing is readily dismissed given that the overall exchange between the licensor and licensee is voluntary and the marginal costs of including additional patents in a license are zero or nearly so. The flaws in the second argument are more subtle and are the subject of the formal analysis below.

Antitrust concern with the packaging of two or more distinct products comes up in other settings, under names such as bundling, tying, and block booking. It is helpful to identify what distinguishes package licensing in our model from these other practices and the related literature.

Package licensing is of particular interest for a number of reasons:

¹ See, e.g., U.S. Department of Justice and Federal Trade Commission, *Antitrust Guidelines for the Licensing of Intellectual Property*, April 6, 1995, §5.3, which also observe that “[p]ackage licensing can be efficiency enhancing under some circumstances.” Some courts have found package licensing unlawful where the licensor refused to license separate patents. See, e.g., *Hazeltine Research v. Zenith Radio*, 388 F.2d 25, 33-35 (7th Cir. 1967), 395 U.S. 100 (1969). These issues also have been addressed by the European Commission. See, e.g., *Guidelines on the application of Article 81 of the EC Treaty to technology transfer agreements*, ¶222(d) (available at http://europa.eu.int/comm/competition/antitrust/legislation/entente3_en.html.)

² Critics of package licensing sometimes assert that a package license containing many patents overwhelms potential licensees’ abilities to evaluate whether they would infringe most or all of the component patents. This is not a bundling issue: the same problem would arise under sequential licensing of the patents.

- Package licenses often contain patents that are strongly complementary in the sense that the underlying intellectual property covered by each patent can be put into application only if one also makes use of the intellectual property covered by the other patents. In these instances, there is no sense in which users have separate valuations of the different patents. Thus, the motive to use bundling or block booking to “average out” valuations across different units does not arise.³
- The technologies covered by patents in a package often are used in fixed proportions. Consequently, packaging complementary patents is not motivated by metering or Ramsey pricing considerations that may arise with other goods.⁴
- The inclusion of additional patents in a package license typically has near-zero incremental cost. From a purely static perspective, even small transaction costs associated with licensing individual patents can make combining patents in a package both socially and privately desirable.
- A licensee may desire a package license to reduce the potential for hold-up. Separate licensing on a patent-by-patent basis exposes a licensee to high royalties for any additional patents that are necessary to produce a commercial product after the licensee has agreed to pay fees for the rights to an initial subset of the necessary patents. A package license that covers all present and future patents owned by a given licensor can reduce this hold-up risk.

³ See, e.g., Adams and Yellen (1976), McAfee et al (1989), and Stigler (1963).

⁴ For an early discussion of using tying to facilitate metering-based price discriminating, see Bowman (1957). For an early (and under-appreciated) discussion of tying to facilitate Ramsey pricing, including the tying of unrelated goods, see Burstein (1960).

Several papers, including Whinston (1990), Choi and Stefanadis (2001), and Carlton and Waldman (2002), have explored how tying can serve as a form of entry (here, innovation) deterrence, but the forces at work for package licensing are very different. The earlier models require a commitment to bundled pricing. In contrast, package licensing of complementary patents is a contractual, not technological tie, and renegotiation is feasible. Furthermore, in Whinston's model, for example, technological tying is a means of committing to a low price in response to entry. In contrast, in our model package licensing serves a function equivalent to raising the post-entry licensee fees for those technologies where entry has not occurred. A related difference between our model and the entry-deterrence literature is that the buyer in our model enters the input market itself, so that it internalizes the gains in consumer surplus due to lower prices.

Below, we examine the welfare properties of equilibrium licensing contracts and how these contracts are affected by the antitrust treatment of package licensing undertaken by a single intellectual property owner.⁵ In our model, a tie in the form of a package license creates pricing flexibility following the entry that may occur through innovation. This flexibility discourages invent-around. At the same time, the package license enables a commitment not to charge prices that exploit sunk complementary investments made by the licensee.

A central finding is that, in many settings, package licensing does not have adverse efficiency effects on invent-around incentives. Intuitively, this is so for two reasons. First, although package licensing may attenuate invent-around incentives in comparison with other types of licensing, this reduction can bring private incentives closer to their socially optimal

⁵ Thus, we do not address the additional issues raised when multiple owners pool their patents into a single license. For an excellent recent analysis, see Lerner and Tirole (2004).

level. To the extent that R&D is motivated solely by the desire to avoid paying royalties for intellectual property that would otherwise be licensed, the innovation gives rise to private benefits, but makes no contribution to total surplus. Second, the argument about incentive effects neglects to account for the fact that a licensor could adjust the license fees for its remaining patents should one of its patents become ineligible for licensing. As we will show, such adjustments can allow the licensor to achieve the effects that critics ascribe to package licensing, and can do so in ways that result in lower welfare than would package licensing.

Our analysis confirms in some respects the standard intuition of the one-monopoly-rent theorem, but in other respects our results differ sharply. If a manufacturer requires a license to use one or both patents *after* investing in R&D and complementary assets, then the intellectual property owner can extract all of the available rent by charging for the use of only one patented technology. This is consistent with the one-monopoly-rent intuition. However, *before* the manufacturer invests in R&D and complementary assets, the allocation of license fees to individual patents can affect the profit that the intellectual property owner is able to derive from its patents because the allocation influences the manufacturer's investment incentives.

The problem of license contract design in our model is related to research on technology transfer with asymmetric information such as Gallini and Wright (1990), Beggs (1992), and Anton and Yao (1994, 2002). The focus of the first two papers is on the design of separating contracts that signal the value of the technology when either the licensor or the licensee has private information. We also derive separating contracts but our focus is on the welfare implications of licensing both patents as a package. The IP incumbent's intellectual property is perfectly protected by patent in our model, which eliminates the risk of expropriation analyzed in Anton and Yao (1994, 2002).

The paper proceeds as follows. Section II lays out the baseline model in which a single incumbent owns a pair of complementary patents that can be used by a single potential licensee to produce final output. Section III characterizes the equilibrium when package licensing is allowed, while Section IV characterizes the equilibrium when component licensing is mandatory. Section V examines several extensions, and the paper closes with a short conclusion.

II. THE BASELINE MODEL

In this section we describe the baseline model, characterize the first-best investments in R&D and complementary assets, and examine the equilibrium under short-term contracting. We use these results to describe equilibrium outcomes with package and component licensing.

A. Model Structure

There is a single final good, production of which requires completion of two processes, X and Y . At the start of the game, there is a single incumbent intellectual property rights holder (the “IP incumbent”) holding two patents, each one covering a technology that can accomplish one of the two processes. The IP incumbent does not have the ability to commercialize the patented technology on its own. Instead, it can offer a license to a single potential licensee (the “manufacturer”). If no licensing takes place, the IP incumbent earns no profit. Unless it has access to technologies covering both processes, the manufacturer cannot engage in production.

There are two types of IP incumbent. A *bad* IP incumbent possesses worthless intellectual property: the gross economic benefits derived from its technology are zero. A *good*

IP incumbent possesses valuable intellectual property.⁶ Let λ denote the ex ante probability that the IP incumbent is good. Throughout, we assume that λ is common knowledge and $\lambda \in (0,1)$.⁷

If it has access to both technologies from a good IP incumbent, the potential licensee derives gross economic benefits of $B(s)$ from production, where s is the level of complementary investment (*e.g.*, plant, equipment, and marketing expenditures) made by the manufacturer before production. The benefit function is bounded from above and twice differentiable, with $B'(s) > 0$ and $B''(s) < 0$ for all $s \in [0, \infty)$. We also assume $B(0) \geq 0$, where cases with strict inequality correspond to settings in which production does not require the manufacturer to make sunk investments in specialized complementary assets.

We assume the manufacturer can invest in R&D that, if successful, yields a perfect, non-infringing substitute for the IP incumbent's good technology.^{8, 9} Innovation is costly and stochastic. The cost of achieving a given probability of success is assumed to be independent of

⁶ We assume that either both processes are good or both are bad, and thus the uncertainty is about the value of the IP incumbent's overall approach. Footnote 24 discusses the effects of relaxing this assumption.

⁷ The importance of the assumption that $\lambda < 1$ is that it prevents the IP incumbent from simply making the manufacturer a residual claimant ($\lambda = 1$ is a special case of Proposition 1 below). This is an important feature because actual licensing contracts often do not take the form of up-front, lump-sum payments alone.

An alternative modeling strategy for ruling out lump-sum licensing contracts is to assume free entry into the supply of bad technology. This strategy was pursued by King (2003). Unfortunately, this strategy does not fit well with our institutional setting, in which the IP incumbent has sought—and been awarded—patents.

⁸ In addition to inventing substitute technology, it may be possible to redesign the product to avoid infringement. The analysis merely involves reinterpreting the “innovation” as “redesign.”

⁹ We assume that the manufacturer is the sole potential innovator in order to avoid problems of three-party bargaining. If we were to have a successful independent innovator, then the entering innovator would have to compete with the IP incumbent to reach a licensing agreement with the manufacturer. The prize to innovation would thus depend on the nature of licensing competition, as well as whether the IP entrant had a prior agreement with the manufacturer, which could be used to avoid the licensee's holding up the entrant.

whether the IP incumbent's technology is good or bad.¹⁰ Specifically, the manufacturer can invent around component technology i with probability q_i by making an R&D investment of $R(q_i)$. The R&D cost function is twice differentiable, with $R'(q) > 0$ and $R''(q) > 0$ for all $q \in (0,1)$. We also assume that $R(0) = 0$, $R'_+(0) = 0$, and $\lim_{q \uparrow 1} R'(q) = \infty$. Lastly, we assume that $R(\cdot)$ and $B(\cdot)$ are common knowledge.

The timing of the game is as follows (the model's timeline is illustrated in Figure 1). There are two stages, the investment stage and the production stage. To simplify the notation, we assume there is no discounting. A contract specifies license fees paid contingent on the manufacturer's use of the IP incumbent's technologies in the production stage. Let L_k denote the license fee paid for use of technology k in the production stage. For example, L_X is the license fee paid if the IP incumbent's technology X is used in production. $k = Z$ refers to a license to use both technologies X and Y . $k = 0$ corresponds to a situation in which the manufacturer does not use either of the IP incumbent's technologies to produce output.¹¹

We assume that a potential licensee can keep secret from a court the fact that it has successfully innovated if it so chooses. Thus, for example, even if the manufacturer has invented around technology Y , it will purchase a license to technology Y if doing so reduces its license payments. Hence, if the manufacturer invents around both of the IP incumbent's technologies, the manufacturer will make its production choices to pay $\min\{L_0, L_X, L_Y, L_Z\}$. Therefore, there is no loss of generality from assuming that L_0 is less than or equal to any other fee. Similarly,

¹⁰ We assume independence for simplicity. None of our central findings hinges on this assumption.

¹¹ In theory, a license contract might distinguish situations in which the manufacturer does not infringe because it does not produce output from situations in which the manufacturer produces output using non-infringing technologies. As will become clear, the proofs of Propositions 1 and 2 would be unaffected by allowing such a distinction.

because the manufacturer can choose to take a license to both technologies even if it has invented around one of them, there is no loss in generality from assuming that

$$L_Z \geq \max\{L_X, L_Y\}.$$

At the start of the first stage, the incumbent offers a license contract to the manufacturer, which the manufacturer accepts or rejects. Because it is reached in the first stage but covers contingencies in the second stage, we refer to this type of agreement as a *long-term contract*. Throughout we assume that the incumbent makes take-it-or-leave-it contract offers and that, in equilibrium, it will choose to make no offer at all rather than make an offer that will almost surely be rejected or that would yield the incumbent zero expected profits if accepted.¹²

We consider two situations. In the first case, the two parties are symmetrically informed at the time the first contract is offered: neither firm knows whether the IP incumbent has good or bad technology. In the other case, it is common knowledge that the IP incumbent knows the quality of its technology but the manufacturer does not.

After choosing whether to accept the first-stage contract, the manufacturer makes investments s , $R(q_X)$, and $R(q_Y)$. It is common knowledge that, at the end of the investment stage, the manufacturer learns the outcomes of its R&D projects and the quality of the IP incumbent's technology. In the asymmetric information case, the timing of investment decisions relative to technology quality revelation is taken to reflect a situation in which the IP incumbent initially has a better sense of its technologies' capabilities and consumers' long-term demand for them than does the potential licensee and, rather than wait for uncertainty to be fully resolved,

¹² Alternatively, one could break the indifference by introducing an arbitrarily small cost of making offers.

the manufacturer begins making needed investments.¹³ In the symmetric case, the IP incumbent also learns the quality of its technology at the end of the investment stage and the timing reflects the fact that both parties may be uncertain about a technology's prospects.

It is common knowledge that the IP incumbent receives signals of s and the outcomes of the manufacturer's R&D projects. In our baseline model, we assume that these signals are perfectly informative, but perfectly unverifiable in court. These informational assumptions are strong, but they serve to illustrate starkly forces that are at work more generally. We also assume that $R(q_X)$ and $R(q_Y)$ cannot be verified in court. Thus, the parties cannot write enforceable contracts directly on the manufacturer's investment levels.¹⁴

At the start of the second stage, the IP incumbent can make a take-it-or-leave-it offer of a new contract to the manufacturer, which the manufacturer chooses to accept or reject. If the manufacturer rejects the offer, then the first-stage contract (if any) remains in effect. Because it covers contingencies for the same period in which it is offered, we refer to an agreement reached at the start of the second stage as a *short-term contract*. If the manufacturer already has accepted a long-term contract in the investment period, then the production-period contract represents renegotiation. We assume that the parties cannot commit not to engage in renegotiation. If the manufacturer accepts the incumbent's contract offer at the start of one or both of the stages, it can produce using the incumbent's licensed technologies in the production stage. Alternatively, the manufacturer can produce using its own technologies if it succeeds in inventing around the patents for both X and Y , or it can produce using a license for one of the technologies and invent

¹³ In the presence of discounting, delaying production would be costly. Alternatively, an earlier version of the model had first-period production that had to be forgone if the investment in plant and equipment were not made before the uncertainty was resolved.

around the other. We assume that the technologies actually used in production are observable and verifiable. Product-market profits are realized at the end of the production stage.

The key difference between long- and short-term contracts is that, under a long-term contract, the values of L_k are set at the start of the first stage, *before* the manufacturer invests in complementary assets and R&D and the manufacturer learns the quality of the IP incumbent's technologies. In contrast, under a short-term contract, the values of L_k are set at the start of the second stage, *after* the manufacturer has invested in complementary assets and R&D, the two parties have received their respective signals of the investment level and project outcomes, and the manufacturer has learned the quality of the IP incumbent's technology.

The legal environment determines whether the licensor must offer independent licenses to the two component technologies, or whether the licensor can choose to offer a single package license for both. Under a *package license*, a single fee covers use of either or both of the technologies: $L_z = L_x = L_y$. We refer to a package license with $L_0 = L_x = L_y = L_z$ as a *lock-in contract* because the license fee is independent of the manufacturer's production-stage actions and is equivalent to a fixed-fee paid up front. At the other pole, under *component licensing*, each technology must be sold separately. That is, there is a set charge for the use of technology i which is independent of whether the other technology is used, and there is no charge for a technology if it is not used. Thus, under component licensing $L_0 = 0$ and $L_z = L_x + L_y$.

¹⁴ Clearly, the IP incumbent could enforce the efficient investment levels if it could contract directly on s , $R(q_x)$, and $R(q_y)$. In practice, however, it is difficult to verify these investments.

The legal environment also specifies whether the IP incumbent can obtain injunctive relief. We assume it can, so that the manufacturer cannot produce unless it either takes a license from the IP incumbent or has invented a non-infringing substitute technology.¹⁵

Our equilibrium concept is perfect Bayesian equilibrium with some sensible restrictions (to be described below) on how out-of-equilibrium actions would be interpreted.

For the analysis that follows, it is useful to introduce the following notation. Let t be a parameter that measures the probability of production by the manufacturer, either because it licenses a good technology or because it invents around the incumbent's patents. Define

$$S^*(t) \equiv \arg \max_s \{tB(s) - s\},$$

$$B^*(t) \equiv B(S^*(t)),$$

and

$$U^*(t) \equiv tB^*(t) - S^*(t).$$

The properties of $B(\cdot)$ imply that $S^*(t) = 0$ for $t \in [0, 1/B'_+(0)]$ and is continuous and strictly increasing for $t \in (1/B'_+(0), 1]$. To avoid trivial cases, assume that $B'_+(0) > 1$ so that $S^*(1) > 0$.

The convexity of $R(\cdot)$ implies that, for any value of the constant u , the solution to

$$\max_{q_X, q_Y} \{q_X q_Y u - R(q_X) - R(q_Y)\} \quad (1)$$

is symmetric. Clearly, the solution is non-decreasing in u , and, given our earlier assumptions, is strictly less than one for any finite u .

At times we assume that the following additional condition is satisfied:

Condition A: $q^2 B^*(1) - 2R(q) < 0$ for all $q \in (0, 1]$.

¹⁵ For interesting analyses of the use of damages and injunctions, see Lanjouw and Lerner (2001) and Schankerman and Scotchmer (2001).

When this condition holds, the solution to Program (1) is $q_X = q_Y = 0$ when $u = B^*(1)$. Clearly, in equilibrium the manufacturer never invests a total of more than $S^*(1)$ in complementary assets. Therefore,

Lemma 1: *Suppose Condition A holds. If it must invent around both patents to obtain a payoff from successful R&D, then the manufacturer undertakes no R&D in equilibrium.*

Condition A implies that package licensing eliminates invent-around incentives—an effect often cited by its critics.

Because Condition A plays a central role in our analysis, it is useful to comment on its plausibility. In Section V.A below, we provide a generalized version of Condition A that allows for more than two patents. Letting n denote the number of patents in the package, the generalized version of Condition A is satisfied if

$$\frac{nR(q)}{B^*(1)} > q^n .$$

The left-hand side of the inequality is equal to the manufacturer's total R&D expenditure divided by its maximal profits from use of the technologies. The right-hand side is the probability of inventing around all n patents. Let m denote the manufacturer's gross margin percentage, excluding costs incurred for R&D and specialized investments, and let Z denote the manufacturer's revenues. Using the fact that $mZ \leq B^*(1)$, the generalized version of Condition A is satisfied whenever

$$\frac{nR(q)}{Z} \frac{1}{m} > q^n .$$

The following calculations are only suggestive, but they indicate that this condition is likely to be satisfied in markets where R&D is costly and a significant number of patents are

offered in a single package. For several high-tech industries, such as medical equipment, semiconductors, software and computer systems, the ratio of R&D to sales ranges from about 9 to 19 percent.¹⁶ Assuming that gross margins are 50 percent and taking the R&D-to-sales ratio to be at the low end of the range, the left-hand side of this inequality is approximately equal to 0.2. Even taking the probability that the manufacturer will successfully design around a patent to be as high as 50 percent, the condition is satisfied for all n greater than or equal to three. Indeed, for industries in which the R&D to sales ratio exceeds 12.5 percent (*e.g.*, software and communications equipment), the condition would be satisfied even for n equal to two.

B. Welfare Benchmarks

For later comparison, consider the socially optimal outcome, where total surplus is our welfare measure. In the baseline model we assume that the manufacturer's customers enjoy no surplus from the product.¹⁷ The *full-information*, first-best outcome depends on whether the IP incumbent has good or bad technology. If the technology is good, then the potential manufacturer licenses the technologies, invests $S^*(1)$ in complementary assets, and undertakes no R&D. The resulting joint profits are $U^*(1)$. If the IP incumbent's technology is bad, then the manufacturer may invest in R&D and complementary assets if Condition A does not hold. When both parties know only λ (the ex ante probability that the technology is good) and the manufacturer must invest in R&D and complementary assets before learning the quality of the incumbent's technology, the *information-constrained* optimal investments are the solutions to

¹⁶ National Science Foundation (2004), Table 4-6.

¹⁷ If consumer surplus were an increasing function of B , the manufacturer would tend to under-invest in complementary assets and—when the IP incumbent has bad technology—R&D. We make this assumption to focus on the marginal distortions due to the form of licensing.

$$\max_{s,q} (B(s)[\lambda + (1-\lambda)q^2] - s - 2R(q)) \equiv \bar{U}.^{18} \quad (2)$$

Under symmetric information, complementary investment is valuable if the licensed technology is good, which occurs with probability λ , or if the technology is bad and the manufacturer invents a substitute, which occurs with probability $(1-\lambda)q^2$. Hence, under the welfare optimum, the manufacturer invests $S^*(\lambda + (1-\lambda)q^2)$ in complementary assets.

C. Short-Term Licensing

If the IP incumbent and manufacturer do not agree on a long-term contract in the first stage, then they will negotiate a short-term contract in the second stage. Suppose that no long-term agreement was reached in the investment stage and consider the short-term contract negotiations at the start of the production stage. Recall that both parties are fully informed in the second stage when the short-term offer and acceptance decision are made. Hence, the IP incumbent can choose license fees that fully extract available surplus from the manufacturer unless the latter has invented around both technologies. For example, if the manufacturer has invented around technology X , but not Y , the good IP incumbent will set $L_Y = B(s)$. The legal treatment of package licensing is irrelevant to short-term licensing because the IP incumbent can tailor the fees for individual technologies in this manner even under component licensing.

Given the fees anticipated under short-term licensing, the manufacturer invests to

$$\max_{q,s} \{q^2 B(s) - s - 2R(q)\} \equiv \pi_0^m. \quad (3)$$

¹⁸ An optimum exists and \bar{U} is well-defined because the objective function is continuous and the actions are chosen from a compact set.

Let \hat{q} and \hat{s} denote the solution to Program (3). Observe that $\hat{q} < 1$ and the manufacturer's marginal incentives to invest in complementary assets are less than the marginal social value of the investment when $\lambda > 0$. Short-term licensing creates a hold-up problem that induces underinvestment in complementary assets. When Condition A is satisfied, the hold-up is particularly severe: Lemma 1 implies that $\hat{q} = 0$ and, thus, $\hat{s} = 0$ as well.

Observe that π_0^m is the manufacturer's reservation expected profit level for accepting a long-term contract in the first stage. A key implication is that—given our assumed information structure—the strength of the credible threat to refuse a long-term contract is independent of whether the IP incumbent engages in package licensing. The manufacturer's threat in bargaining is to innovate. With or without package licensing, the manufacturer earns $B(\hat{s})$ in the second stage if it innovates around both of the incumbent's patents (which occurs with probability \hat{q}^2) and zero expected profits otherwise: short-term licensing takes place after the uncertainty about the R&D has been resolved, and the IP incumbent can replicate the effects of package licensing through appropriately chosen component fees.¹⁹

III. PACKAGE LICENSING

We now examine the use of long-term, package licenses.

A. Symmetric Information

Suppose that it is common knowledge that, at the time the IP incumbent makes a take-it-or-leave-it contract offer at the start of the investment stage, both the manufacturer and the IP

¹⁹ Observe that the irrelevance of packaging under short-term licensing and, thus, packaging's lack of effects on first-period bargaining threat points does not depend on the use of take-it-or-leave-it offers. Of course, the manufacturer might enjoy greater surplus under alternative bargaining models and the hold-up problem could be less severe, which would affect the manufacturer's reservation expected profit level.

incumbent know λ , the probability that the incumbent's technology is good, but neither party knows whether the technology is actually good or bad. This information becomes common knowledge at the start of the production stage.

Consider what happens if the IP incumbent offers a lock-in contract. With symmetric information, the contract offer leads to no updating of beliefs in a perfect Bayesian equilibrium. Because the license payments are fixed, the manufacturer becomes a residual claimant conditional upon taking a license, and thus the manufacturer chooses s and q to maximize total surplus conditional on the information available to the parties, as in welfare benchmark Program (2) above.

Clearly, conditional on offering a contract that is accepted in the first stage, the IP incumbent can do no better than offer a long-term, lock-in contract that satisfies the manufacturer's individual rationality constraint, $L_k = \bar{U} - \pi_0^m$ for $k = O, X, Y$, and Z . Making an offer that is rejected by the manufacturer would yield $(1 - \hat{q}^2)\lambda B(\hat{s})$. This is the IP incumbent's expected payoff from a short-term contract and is less than the IP incumbent would earn with an acceptable long-term contract because

$$\begin{aligned} \bar{U} - \pi_0^m &= \max_{s,q} \{B(s)[\lambda + (1 - \lambda)q^2] - s - 2R(q)\} - \{\hat{q}^2 B(\hat{s}) - \hat{s} - 2R(\hat{q})\} \\ &\geq (1 - \hat{q}^2)\lambda B(\hat{s}), \end{aligned}$$

where the inequality follows by revealed preference. When the parties are symmetrically informed, a lock-in contract supports the information-constrained, socially efficient levels of investment in complementary assets and R&D. Because a lock-in contract is a form of package licensing, we have established:

Proposition 1: *Suppose package licensing is allowed. If the parties are symmetrically informed, then there exists a unique equilibrium: the IP incumbent offers, and the manufacturer accepts, a lock-in contract that yields the manufacturer its reservation profits. The manufacturer undertakes the information-constrained socially optimal levels of investment.*

It follows from Proposition 1 that, with symmetric information, banning package licensing weakly lowers total surplus and the IP incumbent's profits. In fact, as we will show below, banning package licensing can strictly lower total surplus.

B. Asymmetric Information

Now suppose that it is common knowledge that the IP incumbent learns its type before making an initial contract offer, but the manufacturer does not learn the IP incumbent's type until after choosing whether to accept the IP incumbent's first-stage contract offer and making first-stage investment decisions.²⁰

When deciding whether to accept a contract in the first period, the manufacturer must form beliefs about the quality of the IP incumbent's technology. Let μ denote the manufacturer's subjective probability that the IP incumbent has good technology conditional on the IP incumbent's contract offer. Suppose that the IP incumbent offers a long-term package license with $L_X = L_Y = L_Z = L^P$. If the manufacturer accepts the contract, it pays L^P unless it invents around both of the IP incumbent's patents, shuts down production, or renegotiates a lower fee. Absent renegotiation, the manufacturer pays L_0 if it invents around both patents or shuts down. Recall that the IP incumbent makes a take-it-or-leave-it offer in renegotiation after observing s .

²⁰ Several readers have suggested that the first-best could be obtained by having the IP incumbent purchase the manufacturer for a lump-sum amount. Implicitly we are assuming that such a purchase is infeasible because the IP incumbent has limited access to funds (consider an IP incumbent selling a license to Microsoft). Alternatively, a more complex model would have two-sided asymmetric information.

Conditional on the IP incumbent's having good technology, the manufacturer has a credible threat to cease production if and only if $L^p > B(s) + L_0$. Hence, unless the manufacturer invents around both of the IP incumbent's patents, an IP incumbent with good technology will offer a renegotiation contract with a package fee equal to $\min\{L^p, B(s)+L_0\}$. Using the fact that $B(s) - \min\{L^p, B(s)+L_0\} = \max\{-L_0, B(s) - L^p\}$, the manufacturer's expected profit is

$$\begin{aligned} \pi^m = & -(1 - \mu)L_0 + \mu\left((1 - q_X q_Y) \max\{-L_0, B(s) - L^p\} - q_X q_Y L_0\right) \\ & + q_X q_Y B(s) - s - R(q_X) - R(q_Y) \end{aligned} \quad (4)$$

Suppose that Condition A holds and the IP incumbent offers a license with $L_0 = 0$ and $L^p = U^*(1)$. Recall $U^*(1) \equiv B^*(1) - S^*(1)$. This contract yields no profit for an IP incumbent with bad technology, and by assumption such an incumbent does not make this offer. Hence, conditional on this contract offer, the manufacturer expects the IP incumbent's technology to be good, corresponding to $\mu = 1$ in Eq. (4).²¹ By Lemma 1, the manufacturer chooses not to invest in R&D, and the manufacturer's expected profit as a function of s is

$$\pi^m(s) = B(s) - s - \min\{L^p, B(s)\}.$$

By the definition of $U^*(\cdot)$, the package license fee satisfies $B^*(0) \leq L^p \leq B^*(1)$. Therefore,

- If the manufacturer chooses s such that $B(s) \leq L^p = U^*(1)$, it earns $-s$. In this case it should choose $s = 0$ and earn zero.
- If the manufacturer chooses s such that $B(s) > U^*(1)$, it earns $B(s) - s - U^*(1)$. Hence, the manufacturer should conditionally choose $S^*(1)$ and earn zero.

²¹ The full equilibrium beliefs are the following: The manufacturer interprets any offer with $L_0 > 0$ as coming from a bad incumbent with a probability of at least $(1-\lambda)$, while it interprets any contract offer with $L_0 = 0$ as coming from a good incumbent. The beliefs for $L_0 < 0$ are irrelevant.

Assume that, given it earns zero in either case, the manufacturer chooses $s = S^*(1)$. When $L^p = U^*(1)$, the first-best outcome is attained: there is no R&D and s is equal to $S^*(1)$ if the incumbent has good technology and is equal to zero if the IP incumbent has bad technology.

Under any contract, joint profits can be no greater than $U^*(1)$. Therefore, from the perspective of an IP incumbent with good technology, there is no better contract than the one with $L_0 = 0$ and $L^p = U^*(1)$. It follows immediately that:

Proposition 2: *Suppose package licensing is allowed. If the parties are asymmetrically informed and Condition A is satisfied, then there exists an equilibrium in which an IP incumbent with bad technology offers no contract and an IP incumbent with good technology offers a package license. In this equilibrium:*

- (i) *When the IP incumbent has good technology, the manufacturer efficiently invests nothing in R&D and $S^*(1)$ in complementary assets, the manufacturer earns zero profits, and the IP incumbent earns $U^*(1)$.*
- (ii) *When the IP incumbent has bad technology, the manufacturer invests in neither complementary assets nor R&D, and both firms earn zero profits.*

It is useful to discuss the role of Condition A in this result. Absent Condition A, package licensing might fail to attain efficiency because it could not *discourage* R&D investment by the manufacturer.²² Thus, the problem is the opposite of the one asserted by critics of package licensing. This fact also points out that there is a sense in which Condition A is not the driving

²² In addition to creating the possibility of positive equilibrium R&D levels under package licensing, the absence of Condition A raises the possibility that the IP incumbent would lower its license fee in order to reduce the manufacturer's innovation incentives.

force of this result.²³ Instead, it is the fact that the manufacturer's R&D has no social value when the IP incumbent has good technology. We relax this assumption below.²⁴

If one is willing to impose a simple reasonableness condition on the updating of beliefs in response to out-of-equilibrium moves, then any equilibrium must satisfy (i) and (ii) when Condition A is satisfied. Specifically, suppose that in response to an out-of-equilibrium long-term contract offer the manufacturer believes that the IP incumbent has good technology with probability one if the offer is: (a) worthless to an IP incumbent with bad technology, but (b) would yield greater expected profits to an IP incumbent with good technology than would the candidate equilibrium, where (a) and (b) are conditional on the manufacturer's taking the profit-maximizing actions given the belief that the IP incumbent has good technology.²⁵ Then, if (i) or (ii) were not satisfied, either: (a) the IP incumbent with good technology would earn less than $U^*(1)$ and would thus prefer the separating package license above; or (b) at least one of the manufacturer and the IP incumbent with bad technology would earn negative expected profits. It follows immediately from (i) and (ii) that there are no pooling equilibria. Further, observe that

²³ Observe, too, that package licensing would constitute a separating equilibrium under alternative assumptions about contract bargaining. For example, under a model with costly alternating offers, there would exist an equilibrium with a package license with fees falling between 0 and $U^*(1)$. Given the structure of the game, each party would have incentives to propose a package license, which induces an efficient outcome, but each party would have incentives to propose a license fee favorable to itself.

²⁴ It is readily shown that, if the qualities of the IP incumbent's two technologies are imperfectly correlated, then there exists a separating equilibrium in which the IP incumbent with two good technologies offers the contract identified in Proposition 2, an IP with two bad technologies offers no contract, and an IP incumbent with a single good technology offers a component license with a positive fee for that technology.

²⁵ This restriction on beliefs is in the spirit of the Intuitive Criterion offered by Cho and Kreps (1987). Absent such restrictions, there exist equilibria violating both (i) and (ii). For example, a continuum of equilibria similar to the one in Proposition 2 but with lower package fees could be supported by beliefs that any manufacturer that did not offer such a contract must have bad technology. Similarly, if $U^*(\lambda) > 0$, then there exists a range of pooling equilibria with $L_0 = L_X = L_Y = L_Z = U^*(\lambda) - \alpha$ that could be supported by beliefs that any deviating IP incumbent must have bad technology, where $\alpha \in [0, U^*(\lambda))$.

the separating package license above dominates a short-term license given $S^*(1) > 0$.

Summarizing,

Corollary: *Suppose package licensing is allowed. If Condition A is satisfied, the parties are asymmetrically informed, and beliefs are reasonable in the sense defined above, then: (i) there are no pooling equilibria, and (ii) a short-term contract is not an equilibrium license.*

IV. COMPONENT LICENSING

We now examine the possible effects of banning package licenses and requiring the use of component licensing schemes, under which the IP incumbent must offer a long-term license with $L_Z = L_X + L_Y$ and $L_0 = 0$.

A. Symmetric Information

Suppose the parties are symmetrically informed when the first offer is made.

Proposition 3. *If the parties are symmetrically informed and $R''(\cdot) > 0$, then any equilibrium with component licensing entails inefficient investment by the manufacturer.*

Proof: Let s^e be the equilibrium level of investment in complementary assets.²⁶ There are two cases to consider.

²⁶ Proposition 3 presumes the existence of an equilibrium. π_G^m and π_B^m defined in the proof of Proposition 3 are continuous in the manufacturer's investment levels, which can be taken to be chosen from a compact set. Hence, the manufacturer has at least one best response to any pair of license fees. Under the realistic restriction that the license fees are chosen from an arbitrarily large but finite set (e.g., rounded to the penny), there exists at least one optimal pure strategy for the IP incumbent and a pure strategy perfect equilibrium exists.

If the equilibrium strategies involve mixing, then L_X and L_Y are any values that are offered with positive probability in equilibrium, and s^e is any investment level that is made with positive probability in equilibrium conditional on L_X and L_Y having been offered. The same holds for Proposition 4 below.

(i) $\min\{L_X, L_Y\} \geq B(s^e)$. This situation is equivalent to short-term licensing and similarly gives rise to a hold-up problem. The manufacturer invests inefficiently little in complementary assets: $S^*(q_X q_Y)$ rather than $S^*(q_X q_Y + \lambda(1 - q_X q_Y))$.

(ii) $\min\{L_X, L_Y\} < B(s^e)$. The manufacturer's expected profits, gross of the costs for R&D and complementary investments, conditional on the IP incumbent's having good and bad technology, respectively, are

$$\pi_G^m = (1 - q_X)(1 - q_Y) \max\{0, B(s) - L_X - L_Y\} + q_X(1 - q_Y) \max\{0, B(s) - L_Y\} + q_Y(1 - q_X) \max\{0, B(s) - L_X\} + q_X q_Y B(s)$$

and

$$\pi_B^m = q_X q_Y B(s) .$$

For a fixed s , the privately and socially optimal R&D investments maximize

$$\lambda \pi_G^m + (1 - \lambda) \pi_B^m - R(q_X) - R(q_Y) \quad (5)$$

and

$$(1 - \lambda) \pi_B^m - R(q_X) - R(q_Y) , \quad (6)$$

respectively. $R''(\cdot) > 0$ and our other assumptions on $R(\cdot)$ imply there exists a unique solution to

Program (6). Using the facts that $R'_+(0) = 0$ and

$$\frac{\partial \pi_G^m}{\partial q_X} = (1 - q_Y) (\max\{0, B(s^e) - L_Y\} - \max\{0, B(s^e) - L_X - L_Y\}) - q_Y \max\{0, B(s^e) - L_X\} + q_Y B(s^e) > 0 ,$$

any solution to Program (5) must entail higher levels of R&D than the solution to Program (6).

QED

The intuition underlying part (ii) is that there are no social benefits from inventing around the IP incumbent's patents when it has good technology, but there are private benefits to the manufacturer in the form of reduced license payments.

Together, Propositions 1 and 3 indicate that banning package licensing reduces equilibrium total surplus in our baseline model when the parties are symmetrically informed at the time of initial contract negotiations.

B. Asymmetric Information

Now suppose the parties are asymmetrically informed. If there were no hold-up problem (*i.e.*, if, contrary to our baseline assumption, $B^*(0) = B^*(1)$) and Condition A were satisfied, then a ban on package licensing would have no effect. To see why, consider a long-term component license with $L_X = L_Y = B^*(1)$. If the manufacturer were to invent around one of the two technologies, then it would pay $B^*(1)$. If the manufacturer failed to invent around either of the two technologies, then the IP incumbent would have incentives to renegotiate the contract in the second period by offering $L_X + L_Y = B^*(1)$. Thus, a long-term component licensing with renegotiation (or, equivalently, a short-term contract) could replicate the effects of packaging.

Our next results indicate that component contracts are not welfare optimal when there is a potential hold-up problem:

Proposition 4. *If the parties are asymmetrically informed, then relative to the social optimum any equilibrium with component licensing entails the manufacturer's investing too much in R&D or—conditional on the IP incumbent's having good technology—too little in complementary assets.*

Proof: Let s^e be the equilibrium level of investment in complementary assets.²⁷ There are two cases to consider.

(i) $\min\{L_X, L_Y\} \geq B(s^e)$. This situation is equivalent to short-term licensing. As discussed above, the manufacturer invests inefficiently little in complementary assets relative to the social optimum conditional on the IP incumbent's having good technology.

(ii) $\min\{L_X, L_Y\} < B(s^e)$. If the manufacturer believes that there is no chance that the IP incumbent has good technology, then the manufacturer will underinvest in complementary assets conditional on the IP incumbent's having good technology. If the manufacturer believes that there is a strictly positive probability that the IP incumbent has good technology, then by Lemma A.1 in the Appendix the manufacturer will inefficiently undertake a strictly positive amount of R&D. Intuitively, the manufacturer can obtain a positive return by inventing around only one of the patents, and the fact that $R'_+(0) = 0$ implies that the manufacturer invests a strictly positive amount in R&D. Observe too that, if $L_X + L_Y > B(s^e)$, then the manufacturer's marginal return to investment in complementary assets is no greater than $B'(s^e)(q_X + q_Y(1 - q_X))$, which is less than the socially optimal return, $B'(s^e)$. **QED**

Together, Propositions 2 and 4 indicate that banning package licensing reduces equilibrium total surplus in our baseline model when the parties are asymmetrically informed and Condition A is satisfied. Two examples demonstrate that either of the potential distortions identified in Proposition 4 can arise in equilibrium.

²⁷ It is trivial to construct equilibria. It is readily shown, for example, that $L_0 = 0$ and $L_X = L_Y = U^*(1)/3$ is an equilibrium when the manufacturer believes that the IP incumbent has good technology if it offers this contract and bad technology otherwise. Given that Proposition 4 applies to *any* equilibrium, we do not attempt to identify specific examples of equilibria based on reasonable beliefs.

Our first example shows that banning package licensing may lead to excessive R&D in situations where the manufacturer would not invest in complementary assets with either a short-term contract or a component license that always induced renegotiation. In these situations, at least one of the second-stage license fees must be less than the equilibrium value of $B(s)$ to induce complementary investment, but such fees also induce the manufacturer inefficiently to invest in trying to invent around the other patent. Suppose $S^*(\lambda) = 0$, $B(0) = 0$, and Condition A is satisfied. When package licensing is allowed, the IP incumbent will offer a separating contract that supports the first-best outcome. Suppose packaging is banned. A short-term license or a long-term component license with $\min\{L_X, L_Y\} \geq B(s)$ would induce $s = 0$ and yield zero profit for both the IP incumbent and the manufacturer. Given $S^*(\lambda) = 0$, a pooling component contract would yield zero profit as well. However, there exist profitable separating component contracts with $\min\{L_X, L_Y\} < B(s)$. For example, a component license with $L_0 = 0$ and $L_X = U^*(1)/2 - \varepsilon = L_Y$, where ε is a small positive number, would yield positive incumbent profits because: (a) the manufacturer would accept the contract ($q_X = 0 = q_Y$ and $s = S^*(1)$, for example, would yield positive manufacturer profits); and (b) the manufacturer never finds it profitable to invent around both patents with probability one. By Lemma A.1, the manufacturer will conduct some R&D even when the IP incumbent is revealed to have good technology.

Our second example demonstrates that a ban on package licensing can adversely affect investment in complementary assets. Suppose that $B^*(0) = \frac{7}{8} B^*(1)$ and $R(q) = B^*(1)q^2$. By Proposition 2, the equilibrium outcome when package licensing is allowed has the first-best levels of investment in R&D and complementary assets. Suppose, counterfactually, that component licensing also leads to the first-best investment in complementary assets. Then

component licensing must lead to a separating equilibrium, with $s = S^*(1)$ when the IP incumbent has good technology. $L_0 = 0$ in a separating equilibrium. Moreover, the manufacturer will choose $s = S^*(1)$ only if there is no renegotiation. Hence, the manufacturer's expected profit under component licensing conditional on the IP incumbent's having good technology is

$$\begin{aligned} \pi^m = & (1 - q_X)(1 - q_Y)(B^*(1) - L_X - L_Y) + q_X(1 - q_Y)(B^*(1) - L_Y) \\ & + q_Y(1 - q_X)(B^*(1) - L_X) + q_X q_Y B^*(1) - S^*(1) - R(q_X) - R(q_Y) . \end{aligned} \quad (7)$$

Differentiation of the right-hand side of Eq. (7) yields $\frac{\partial \pi^m}{\partial q_i} = L_i - R'(q_i)$, $i = X, Y$. Using the fact

that $R(q) = B^*(1)q^2$, the manufacturer's profit-maximizing R&D satisfies $q_i = \frac{L_i}{2B^*(1)}$.

Because $L_i > B^*(1)$ would trigger renegotiation for any $q_i < 1$, it must be the case that $q_i \leq \frac{1}{2}$ in equilibrium. It follows that the IP incumbent's licensing revenues must be less than or equal to the maximized value of the following program:

$$\begin{aligned} \max_{L_X, L_Y} & \left(1 - \frac{L_X}{2B^*(1)}\right)L_X + \left(1 - \frac{L_Y}{2B^*(1)}\right)L_Y \\ \text{s.t.} & L_X + L_Y \leq B(1) . \end{aligned}$$

The solution to the program above is $L_X = \frac{1}{2} B^*(1) = L_Y$, which yields profits of $\frac{3}{4} B^*(1)$.

Hence, the IP incumbent can earn no more than $\frac{3}{4} B^*(1)$ under any component licensing contract that induces $s = S^*(1)$. But a component license that always triggered renegotiation and thus induced $s = S^*(0)$ would yield greater profits. Therefore, $s < S^*(1)$ under component licensing.

V. EXTENSIONS

In this section, we consider several variants and generalizations of our baseline model.

A. More Patents and More Production Stages

The baseline model with symmetric information readily generalizes to the case of more than two patents or multiple production periods. When there are multiple production stages, the IP incumbent has another tool for circumventing a prohibition on package licensing. In particular, suppose that there are two production periods, one of which occurs before the manufacturer can complete any projects to invent around the IP incumbent's technologies. Then the license fees collected in those periods can act as up-front payments that (partially) replicate the effects of a lock-in contract. For example, if $\lambda = 1$ and $U^*(2) < B^*(2)$, then by choosing ε sufficiently small, the IP incumbent could come arbitrarily close to attaining the effects of a package license by setting $L_X = L_Y = U^*(2)/2 - \varepsilon$ for use of the technologies in the first production period, and $L_X = L_Y = \varepsilon$ for their use in the second production period.

In order to generalize our analysis of the asymmetric information case to n patents and T production periods, one can use the following extension of Condition A:

$$\frac{R(q)}{q^n} > \frac{TB^*(T)}{n} \text{ for all } q \in (0,1] .$$

Observe that this becomes a weaker condition as the number of patents, n , rises because, for a given $R(\cdot)$, $B(\cdot)$, and q , the left-hand side of the inequality rises with n while the right-hand side falls. It becomes a stronger condition, however, as the number of production periods, T , rises because the manufacturer can amortize its R&D over more production. Of course this condition could be weakened if future benefits were discounted. An interesting question for future research is whether a sequence of overlapping multi-period contracts can provide efficient investment incentives in cases where the economic life of complementary capital is more than

one period, while at the same time providing the IP incumbent with the flexibility to adjust its license fees in response to successful innovation by the manufacturer.²⁸

B. Socially Valuable R&D

One possible objection to our baseline model is that we minimize the chance that package licensing can harm welfare because we assume that successful R&D yields technology that is no better than the IP incumbent's good technology. It is readily seen, however, that relaxing this assumption would be inconsequential in the symmetric information case. Under a lock-in contract, the manufacturer is the residual claimant to the benefit of any improvements due to R&D and thus has private incentives equal to the social benefits (given our maintained assumption that consumer surplus is unaffected).

The situation is more complex in the asymmetric information case. We will now show that package licensing can lead to insufficient incentives to invest in superior technologies in some cases, but can lead to the manufacturer's having socially *excessive* R&D incentives in others. Moreover, package licensing can stimulate R&D in comparison with the short-term contracts that might arise if package licensing were banned.

Suppose that, if the manufacturer succeeds in inventing around the IP incumbent's patent $i \in \{X, Y, Z\}$, then the gross benefit function from the product market is $\gamma_i B(\cdot)$, where $\gamma_i \geq 1$ and $\max\{\gamma_X, \gamma_Y\} \leq \gamma_Z$.²⁹ Also suppose that the value of λ is sufficiently small that there is no pooling

²⁸ The work of Rey and Salanie (1990 and 1996) demonstrates the power of overlapping, intermediate-term contracts.

²⁹ Now there is an opportunity cost of using the IP incumbent's technologies if the manufacturer has successfully innovated, so we can no longer simply assume that $L_0 \leq L_i \leq L_Z$, for $i = X, Y$. Moreover, there is a distinction between not using the IP incumbent's technologies and shutting down. However, splitting L_0 into two components would not matter below—both still would have to be less than or equal to zero to avoid pooling.

equilibrium because the manufacturer would choose $s = 0$ and $B(0) = 0$. Conditional on accepting a long-term package license from a licensor it believes has good technology, the manufacturer chooses s , q_X , and q_Y to maximize

$$\begin{aligned} \pi^m = & (1 - q_X)(1 - q_Y) \max\{0, B(s) - L^p\} + q_X(1 - q_Y) \max\{0, \gamma_X B(s) - L^p\} \\ & + q_Y(1 - q_X) \max\{0, \gamma_Y B(s) - L^p\} + q_X q_Y \gamma_Z B(s) - s - R(q_X) - R(q_Y). \end{aligned}$$

The derivative of expected manufacturer profits with respect to q_X is

$$\begin{aligned} & (1 - q_Y) \left(\max\{0, \gamma_X B(s) - L^p\} - \max\{0, B(s) - L^p\} \right) \\ & + q_Y \left(\gamma_Z B(s) - \max\{0, \gamma_Y B(s) - L^p\} \right) - R'(q_X). \end{aligned}$$

In contrast, the marginal social value of R&D is

$$(1 - q_Y) (\gamma_X B(s) - B(s)) + q_Y (\gamma_Z B(s) - \gamma_Y B(s)) - R'(q_X).$$

The difference between the marginal gross private and social returns with respect to q_X is

$$(1 - q_Y) \left(\min\{B(s), L^p\} - \min\{\gamma_X B(s), L^p\} \right) + q_Y \min\{\gamma_Y B(s), L^p\}. \quad (8)$$

If $B(s) > L^p > 0$, then Expression (8) is positive for positive q_Y . A similar expression holds for the incentives to invent a new technology Y . In the Appendix, we show by example that $B(s^e) - L^p > 0$ can arise in equilibrium, where s^e is the equilibrium value of s . Hence, when R&D undertaken by the manufacturer can yield technology that is superior to the IP incumbent's good technology, package licensing may induce socially excessive R&D.

This finding can hold even when Condition A is satisfied. That condition implies that the manufacturer would not undertake R&D solely to avoid having to pay a package license fee. However, even when the condition holds, the manufacturer may engage in R&D with a package license if R&D can produce a more valuable technology. Under these circumstances, the

possibility of avoiding the license fee creates an additional private—but not social—benefit and can lead to excessive investment in R&D.

Now suppose that $\gamma_Y = 1$, $\gamma_X = \gamma_Z > 1$, and $L^P > 0$. If $L^P \geq \gamma_Z B(s^e)$, then the manufacturer would earn profits in the production stage only if it invented around both of the IP incumbent's patents. For some values of $R(\cdot)$ and $B(\cdot)$, these conditions would induce the manufacturer to refuse a license, make no investments, and shut down, which yields zero profit for the IP incumbent. Hence, when those conditions are satisfied, $L^P < \gamma_Z B(s^e)$ and Expression (8) is equal to $\min\{B(s), L^P\} - (1 - q_Y)L^P$. One can make L^P large by increasing γ_X , while making q_Y small through the choice of $R(\cdot)$. Hence, for some parameter values, the difference between the marginal gross private and social return to R&D is negative. The source of the distortion is that renegotiation occurs on the equilibrium path when the manufacturer invents around one patent but not the other. Renegotiation leads to a hold-up problem with respect to R&D investment. The IP incumbent raises its license fee demand in renegotiation when it observes that the manufacturer has developed an improved version of one technology but still needs to take a license from the IP incumbent for the other technology.³⁰

Although package licensing can inefficiently attenuate R&D incentives, it is not evident that this is a problem with packaging per se. Consider, for example, the effects of short-term licensing. Under short-term licensing, the equivalent of second-stage renegotiation occurs in all states of the world. Thus, under short-term licensing, the manufacturer gets no benefits from R&D unless it invents around both of the IP incumbent's patents simultaneously. This is so even

³⁰ A similar effect is identified and analyzed in Choi and Stefanadis (2001).

though successfully inventing around a single patent yields the manufacturer a technology superior to the incumbent's.

Lastly, suppose that, in addition to increasing the gross benefits available to the manufacturer and IP incumbent, successful R&D generates benefits that are appropriated by consumers. Because the manufacturer does not count the increase in consumer surplus as a benefit, there is a downward bias in its R&D incentives. As is typical in the theory of the second best, the distortions identified earlier in this subsection could offset or exacerbate this bias. There is, however, no direct link between the IP incumbent's use of package licensing and the manufacturer's ability fully to appropriate consumer benefits.

C. An Uninformed IP Incumbent

The baseline model assumes that, prior to making a second-stage contract offer, the IP incumbent observes perfect signals of the manufacturer's first-stage investment in complementary assets and R&D. Consider the baseline model again, except now make the assumption that the IP incumbent receives perfectly uninformative signals.

This alternative information structure can affect the equilibrium under short-term contracting or under component licensing that would otherwise entail renegotiation along the equilibrium path. Consider the case of short-term licensing when the IP incumbent cannot observe the manufacturer's investment in complementary assets. It is readily shown that there can be no pure strategy equilibrium. If the manufacturer set $s = \hat{s}$ with probability one, then the IP incumbent would set its short-term license fee equal to $B(\hat{s})$ as long as the manufacturer did not invent around both patents. But then the manufacturer would choose $\hat{s} = 0$. However, if the short-term license fee were always $B(0)$, then the manufacturer would choose $S^*(1)$. Thus, there is no pure-strategy equilibrium. Observe that the mixing by the manufacturer occurs over non-

negative values of s , so that the hold-up problem is partially solved. Observe too that there may be inefficient shut-down when the manufacturer chooses a relatively low value of s and the IP incumbent chooses a relatively high value for its short-term license fee.

Next, suppose that the IP incumbent can observe s , but has no information about the outcome of the manufacturer's R&D. Now, a short-term contract no longer provides a means of evading a prohibition on package licensing. Because it cannot observe the outcome of the manufacturer's R&D, the IP incumbent cannot tailor its short-term contract offer to the outcome of the manufacturer's R&D. Thus, even with short-term licensing, the IP incumbent would like to be able to practice package licensing by setting $L_Z = L_X = L_Y = B(s)$ in its contract offer. Note that, if it cannot make a package offer, the IP incumbent may choose high values of L_X and L_Y to extract rents from the manufacturer conditional on its having invented around one of the two patents, even though doing so will deter the manufacturer from taking a short-term license if both of its invent-around attempts fail (*i.e.*, $L_X + L_Y$ may be greater than $B(s)$). Moreover, if package licensing is banned, then the manufacturer must conduct R&D with positive probability in equilibrium. To see why, suppose to the contrary that $q_X = 0 = q_Y$ with probability one. Then the IP incumbent would offer a short-term license with $L_Z = B(s)$. But then the IP incumbent would have positive incentives to invent around at least one of the IP incumbent's two patents because the minimum of L_X and L_Y would have to be strictly less than $B(s)$.

When long-term package licensing is feasible, there is no renegotiation on the equilibrium path after the signals are realized. However, the threat points are determined by the manufacturer's option of refusing to sign a long-term contract. Thus, although the IP incumbent can still attain a first-best outcome under the conditions identified in Propositions 1 and 2, the IP incumbent may have to offer a package license that yields the manufacturer information rents.

VI. CONCLUSION

The economic effects of package licenses are more subtle and complex than popular intuition asserts. Although based on strong assumptions, our simple formal model illustrates several broader points that apply to package licensing when the licensor knows the licensee's values of the patents. First, prohibiting package licensing can result in equilibrium contracts that induce inefficient invent-around R&D in situations where package licensing would forestall it. In other cases, the licensee's incentives to innovate may be socially excessive even under package licensing. Second, shorter contracts can be a (partial) substitute for package licensing. For some settings in our model, the IP incumbent can use short-term contracting to adjust its contract offer after the uncertainty about innovation has been resolved and can thus fully exercise whatever market power remains. More generally, this analysis indicates that—absent the ability to engage in packaging—licensors may shorten the length of pricing commitments and thus retain flexibility to respond to changes in the ability to collect fees for specific patents. One of the effects of prohibiting package licensing can thus be to induce the private parties to adopt contracts that result in less efficient complementary investment because of hold-up problems. Third, when there are multiple production periods, a long-term component contract under which some payments are made before any innovation has taken place can also serve as a (partial) substitute for package licensing in some circumstances. Lastly, although our formal model takes the IP incumbent's technology as given, a clear implication of this analysis is that package licensing can increase the original innovator's initial incentives to undertake R&D.

There clearly remain a number of extensions that must be addressed before we have a full understanding of package licensing. A model with a more general set of bargaining institutions would be useful, as would one in which Condition A is relaxed. Results without Condition A are

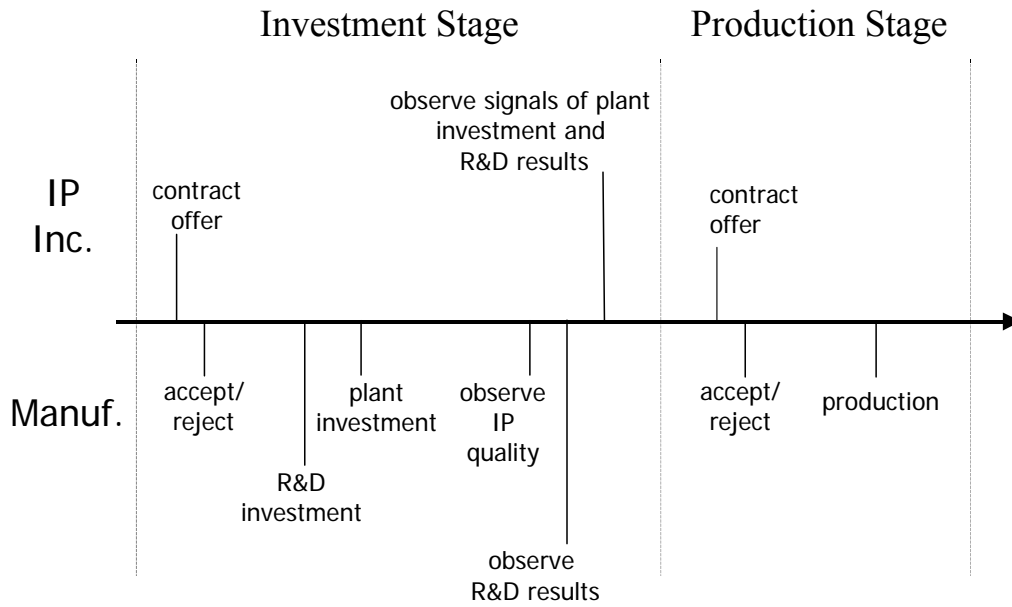
difficult to obtain for general convex R&D cost functions because the IP Incumbent's profit need not be a concave function of the license fees. It also would be worthwhile to examine additional institutional settings, including those in which the potential innovator were a third party, the potential licensee had better information about its valuation of the patented technology than did the potential licensor, or the parties were asymmetrically informed about the costs of innovation. We note that this type of model could also be extended to analyze the effects of package licensing on a potential intellectual property user's incentives to pursue litigation to have patents declared invalid, un infringed, or unenforceable, or even extended to the more general phenomenon of contractually tying complementary goods in order to deter two-stage entry in markets where buyers may sponsor entry. Lastly, the analysis of the present paper could be extended to the case of package licensing by patent pools in situations where design-around innovation by non-pool members is possible.

REFERENCES

- Adams, William J., and Janet L. Yellen (1976) "Commodity Bundling and the Burden of Monopoly," *Quarterly Journal of Economics*, **90**: 475-98.
- Anton, James J. and Dennis A. Yao (1994), "Expropriation and Inventions: Appropriable Rents in the Absence of Property Rights," *American Economic Review*, **84**(1): 190-209.
- Anton, James J. and Dennis A. Yao (2002), "The Sale of Ideas: Strategic Disclosure, Property Rights, and Contracting," *Review of Economic Studies*, **69**(3): 513-531.
- Beggs, A.W. (1992), "The Licensing of Patents under Asymmetric Information," *International Journal of Industrial Organization*, **10**: 171-191.
- Bowman, Ward S. (1957) "Tying Arrangements and the Leverage Problem," *Yale Law Review*, **67**: 19-36.
- Burstein, Meyer L. (1960) "The economics of tie-in sales," *Review of Economics and Statistics*, **42**(1): 68-73.
- Carlton, Dennis W., and Michael Waldman (2002) "The Strategic Use of Tying to Preserve and Create Market Power in Evolving Industries," *RAND Journal of Economics*, **33**(2): 194-220.
- Cho, In-Koo, and David M. Kreps (1987) "Signalling Games and Stable Equilibria," *Quarterly Journal of Economics*, **102**: 179-221.
- Choi, Jay Pil, and Christodoulos Stefanadis (2001) "Tying, Investment, and the Dynamic Leverage Theory," *RAND Journal of Economics*, **32**(1): 52-71.
- Gallini, Nancy T. and Brian D. Wright (1990), "Technology Transfer under Asymmetric Information," *RAND Journal of Economics*, **21**(1): 147-160.
- King, John T. (2003) "The Sale of Unprotected Inventions under Alternative Models of Contracting Behavior," *International Journal of Industrial Organization*, **21**: 57-77.
- Lanjouw, Jean, and Joshua Lerner (2001) "Tilting the Table? The Use of Preliminary Injunctions," *Journal of Law and Economics*, **44**: 573-603.

- Lerner, Joshua, and Jean Tirole (2004) "Efficient Patent Pools," *American Economic Review*, **94**: 691-711.
- McAfee, R. Preston, John McMillan, and Michael D. Whinston (1989) "Multiproduct Monopoly, Commodity Bundling, and Correlation of Values," *Quarterly Journal of Economics*, **104**: 371-84.
- National Science Board (2004) *Science and Engineering Indicators 2004*, Arlington, VA: National Science Foundation.
- Rey, Patrick, and Bernard Salanie (1990) "Long-Term, Short-Term and Renegotiation: On the Value of Commitment in Contracting," *Econometrica*, **58**(3): 597-619.
- _____ and _____ (1996) "On the Value of Commitment with Asymmetric Information," *Econometrica*, **64**(6): 1395-414.
- Schankerman, Mark, and Suzanne Scotchmer (2001) "Damages and injunctions in protecting intellectual property," *RAND Journal of Economics*, **32**(1):199-220.
- Stigler, George J. "United States v. Loews, Inc.: A Note on Block Booking," in *Supreme Court Review: 1963*, Philip B. Kurland (ed.), Chicago: University of Chicago Press: 152-57.
- Whinston, Michael D. (1990) "Tying, Foreclosure, and Exclusion," *American Economic Review*, **80**: 837-59.

Figure 1: The Basic Timeline



APPENDIX

Lemma A.1: *If $\min(L_X, L_Y) < \min\{B(s^e), L_Z\}$, then $q_X + q_Y > 0$ in equilibrium.*

Proof: Let μ denote the manufacturer's subjective probability that the IP incumbent has good technology conditional on the IP incumbent's contract offer. Then

$$\begin{aligned} \frac{\partial \pi^m}{\partial q_X} &= \mu \left\{ (1 - q_Y) \left(\max\{0, B(s^e) - L_Y\} - \max\{0, B(s^e) - L_Z\} \right) - q_Y \max\{0, B(s^e) - L_X\} \right\} \\ &\quad + q_Y B(s^e) - R'(q_X) \end{aligned}$$

and

$$\begin{aligned} \frac{\partial \pi^m}{\partial q_Y} &= \mu \left\{ (1 - q_X) \left(\max\{0, B(s^e) - L_X\} - \max\{0, B(s^e) - L_Z\} \right) - q_X \max\{0, B(s^e) - L_Y\} \right\} \\ &\quad + q_X B(s^e) - R'(q_Y) \end{aligned}$$

Suppose $q_X = q_Y = 0$. Then $\frac{\partial \pi^m}{\partial q_X} = \mu \left\{ \max\{0, B(s^e) - L_Y\} - \max\{0, B(s^e) - L_Z\} \right\}$ and

$\frac{\partial \pi^m}{\partial q_Y} = \mu \left\{ \max\{0, B(s^e) - L_X\} - \max\{0, B(s^e) - L_Z\} \right\}$. If $\min(L_X, L_Y) < \min\{B(s^e), L_Z\}$, then

either $\frac{\partial \pi^m}{\partial q_X} > 0$ or $\frac{\partial \pi^m}{\partial q_Y} > 0$ when $q_X = q_Y = 0$, a contradiction. **QED**

Example showing that $B(s^e) - L^p > 0$ can arise in equilibrium. Suppose that, for some

$\bar{q} \in (0, 1)$, $\lim_{q \uparrow \bar{q}} R'(q) = \infty$, $S^*(\bar{q}(2 - \bar{q})\gamma_Z B(1)) = 0$, $B(0) = 0$, and $S^*(1) > 0$. If the IP incumbent

set $L^p \geq B(s^e)$ in equilibrium, then the manufacturer would earn profits in the second period only

if it invented around at least one of the IP incumbent's patents. Thus, the expected gross benefits

to the manufacturer from investment in complementary assets are less than or equal to

$\{\bar{q}(2 - \bar{q})\gamma_Z\}B(s)$. But, by assumption, $S^*(\bar{q}(2 - \bar{q})\gamma_Z B(s)) = 0$. Therefore, the manufacturer

would make no investment in complementary assets, and the IP incumbent would earn no

licensing revenues. Given that $S^*(1) > 0$ and $\bar{q} < 1$ (this follows from the other assumptions), the IP incumbent could earn positive expected revenues by setting L_Z sufficiently small, but positive. Therefore, $L^p < B(s^e)$ in equilibrium.