Inter-Temporal Tie-Ins: A Case For Tying Intellectual Property

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Hybrid licences tie trade secret rights (which have no fixed expiration) to related patent rights (which expire). Although level royalty hybrid licences, which charge a single royalty for both rights, have been prohibited, it can be shown that infinite-term licensing (ITL) for patent rights may be better than a limited-term patent, when returns to the licensor are fixed. This paper explains hybrid licensing as a means of privately implementing the efficient ITL outcome when returns to the licensor are constrained but not necessarily fixed, without requiring a change in the length of the patent term.

Keywords: hybrid licensing, intellectual property rights, patents, trade secrets, tying.

(*JEL* Classifications: K11 Property law; K21 Antitrust law; L42 Vertical restraints.)

I. INTRODUCTION

Intellectual property rights such as patents and trade secrets permit innovators to reap the rewards of their efforts. This paper analyzes the practice of tying intellectual property in hybrid licences, which are contracts that package trade secret rights with related patent rights. Since trade secret contracts for the transfer of know-how are not required by law to terminate after a fixed period, unlike patent contracts, hybrid licences can be a private mechanism for extending licences involving patented innovations to periods beyond a limited patent term. In general, tying is *per se* illegal. Should this law extend to contracts involving intellectual property?

In this paper, I demonstrate that the answer is no. A better response would be to evaluate hybrid licensing arrangements, alleged to involve misuse of market power provided by the patent grant, under a rule of reason. Earlier research has advanced leveraging and metering arguments for tying, showing that for items without intellectual property protection making tying arrangements *per se* illegal is too strict, in that the social benefits from tying can outweigh the possible anti-competitive effects.[1] The results in this paper are consistent with this conclusion but the arguments concerning efficiency are distinct. What is at issue here is the means of achieving a more efficient royalty structure through tying. The model of hybrid licensing developed below indicates that where a licensor would offer a licence with royalties that vary with output and the licensor is constrained (by the outside opportunities of potential licensees) to reduce the rate of the hybrid royalty below the rate of the corresponding patent-only royalty to induce the licensee to accept the licence, then the tying inherent in the hybrid contract can be socially efficient.

The primary purpose of the paper is to provide examples of socially efficient hybrid licensing to make a case for the tying of intellectual property rights. However, for the tying arrangement to be offered privately, this form of licence must be the type chosen by the licensor.

Licences can take a number of forms, not all of them involving tying nor even the transfer of know-how as a trade secret.

Intellectual property licences typically contain payment clauses which specify that the licensee will pay a fixed fee, independent of the level of output, and/or royalties, which accrue per unit of output or as a percentage of sales.[2] The data of Macho-Stadler, Martinez-Giralt, and Perez-Castrillo [1993], a recent study of licence design in Spain, "confirm that most of the contracts have a very simple structure:...86.3% of the contracts are linear (in many cases degenerated, in the sense that they are based either on fixed fees or variable payments only)."[3] Of the simpler contracts, 59.3% have only royalty payments, 27.8% have only a fixed fee, and the remaining 12.9% have both. Only 15.8% of these contracts involved patents; the rest covered transfers of property rights such as franchises, trade marks, and industrial designs.

Regarding the prevalence of know-how in the transfer of property rights in the U.S., Jorda [1986] "estimated that of all industrial property licensing agreements about 50% cover pure trade secrets and another 20-30% are of the hybrid variety."[4] An earlier survey, Rostoker [1983], "concerning the subject matter of licensing agreements revealed that the majority (58%) contained both patent and know-how components [and] another 32% of the licences were strictly for patent rights, while only 10% were concerned solely with know-how."[5]

The inclusion of know-how in licensing seems to have some impact on the choice of contract form. Of the sample of licences used by Macho-Stadler *et al.* in their analysis, "transfer of know-how is encountered in 52% of the contracts. These contracts tend to be based on variable payments (69%), while 55% of the contracts that do not transfer any know-how are based on fixed fees."[6] When this sample is restricted to include only those contracts involving patents -- 55.3%

of these contracts also involving know-how -- the proportions rise: 80.9% of the licences with both patents and know-how are based primarily on variable payments while payments in 52.9% of patent-only licences are predominantly fixed fees.

Typically, the transfer of know-how in these and other more theoretical studies is assumed to be the sale of some valuable technical information that cannot be patented. In this paper, in order to focus attention on the choice of licence length, the know-how which is tied to the patented innovation is "fictional", without any value, introduced solely for the purpose of extending the licence beyond the patent term.[7]

A licensor's preference for royalties over fixed fees can arise from recognition of the strategic implications of licensing which alters the cost structures of producing firms, as examined here. The cost structure can be changed for the entire industry, such as when a licensor chooses to increase the marginal costs of her licensees in order to induce the licensees to restrict output to an amount closer to the monopoly level, raising industry profits while the licensor extracts these higher profits through the royalty and perhaps also a fixed fee. The licensor can also threaten to use royalties to affect the relative cost structure within an industry. For example, a potential licensee may accept a less favourable licence with a higher royalty rate than he would have in the absence of strategic considerations from fear of the threat of a competitor receiving a very favourable exclusive licence with a low royalty rate that confers a cost advantage. The strategic licensing motivation for the use of per-unit royalties is explicitly considered in the analysis below.

Macho-Stadler *et al.* note that "a characteristic of contracts containing transfer of know-how is the importance of royalties" as opposed to fixed fees within the payment schedule. They offer two additional explanations for this importance -- both stemming from asymmetries in

information -- asserting that the use of royalties "reduces the moral hazard temptations of not transferring all the know-how...[and] signals helpful know-how, separating it from the low-valued...know-how."[8] In this paper, results will be derived for licences in which fixed fees are assumed to be unavailable (restricted to zero) to provide some insight into the outcomes that may obtain when either of the reasons advanced by Macho-Stadler *et al.* hold.

The model will not only establish the form of the licence chosen by the licensor to determine the circumstances under which hybrid licences would be chosen, but also provide the means to evaluate the claim that some licences with tied hybrid royalties are socially more efficient than their patent royalty counterparts that do not involve tying.

Social efficiency is typically maximized when licences contain only fixed fees, since these represent lump-sum transfers from licensees to licensors and do not affect production decisions at the margin. However, given the widespread use of variable payments in intellectual property licences, intellectual property policy should reflect consideration of the effects of these variable payments or royalties.

A fundamental trade-off in designing an optimal patent policy arises from conflict between the incentive for invention and the desire for efficient diffusion.[9] However, this problem is partially separable: optimal diffusion mechanisms can be derived subject to the condition that they provide returns to innovation sufficient to ensure a desired level of research and development. There are (at least) two ways to pursue this derivation. The first method is to assume, *ex ante*, a fixed level of return that must be achieved for any innovation and adjust patent policy parameters to maximize the efficiency of diffusion subject to that constraint. The second is to assume that the prevailing minimum level of reward induced sufficient inventive activity to generate a given

innovation and adjust licensing policy for efficient diffusion, while constraining the returns to vary within the feasible range that arises from market conditions and patent parameters. This paper follows the second, *ex post*, method of analysis. One conclusion, of either route, is that allowing returns for innovation to accrue over a longer period than the limited patent term can be a more efficient way to reward an innovator.

The logic, following the first route, flows from an application of results from Tandon [1982] and Gilbert and Shapiro [1990].[10] These results arise from the observation that for a given return to an innovator deadweight loss from per-unit royalties is minimized when the accompanying distortion is spread out over a longer period of time.[11] If there is a deadweight loss of Ω per period associated with the patent, then the social problem is to minimize ΩT for the T periods of the patent grant. The innovator will receive profits per period of π for the patent term, *i.e.*, πT in total. Minimizing ΩT is equivalent to minimizing the ratio of deadweight loss to profit, given a fixed return to the innovator, since $\Omega T = (\Omega/\pi)\pi T$. To minimize Ω/π, reduce the royalty rate to its lowest level. Since πT is fixed, the lowest royalty rate obtains where T is largest.[12] This approach suggests that if returns to the licensor could be fixed, infinite-term licensing (ITL) would be the most efficient method of diffusion, given the intellectual property rights assigned to innovations.

This paper departs from this earlier path in that returns to the patent-holder are not fixed *ex ante* at some pre-determined level: the licensor is left free to select licence terms. Efficient infinite-term licensing can result when the licensor's choice of licence terms is constrained by the pre-set limit to the patent term, T, and by a potential licensee's ability to obtain returns without the innovation. Under these constraints, with a hybrid licence the licensor must reduce the royalty

rate during the patent term to raise the rate in the post-patent period. In a patent-only licence, the royalty rate must fall to zero with the expiration of the patent. Tying allows the extension of the licence into the post-patent period; however, typically, the licensor must relinquish some returns during the patent-period in order to gain this licence extension. To arrive at an equilibrium in which the licensor chooses to tie, her returns must be at least as large, if not larger, under the hybrid licenses that involve tying as when she doesn't tie. The model developed below demonstrates that even without fixing the returns to the patent-holder before licensing occurs, the benefits of the ITL result may be obtained regarding optimal diffusion: if the licensor charges per-unit royalties, the most efficient licensing structure often has the lowest royalty rate and the longest term.

However, current patent rules limit the term of the patent. One way to circumvent this restriction without altering T is to tie the use of the patent to a trade secret licence which is not restricted to a finite life. Hybrid licensing can act as a private version of infinite-term licensing (ITL) of patented rights: where there exists an incentive to write a hybrid licence, this private contract can reach the ITL solution in the limit (as licence length goes to infinity). The ITL solution has the advantage that the royalty stream is smoother: without a hybrid licence, royalties are relatively high for the duration of the patent, then drop to zero; under hybrid licensing, if the royalties are lower during the patent period although greater than zero afterward, efficiency losses from distortionary royalties can be postponed and reduced. This paper does not focus on arguments for or against limiting the length of the patent term; instead, the discussion here centres on other policy instruments that can be used to adjust for some of the effects of a limited patent term.[13] These alternate policy instruments, which may be less complex to administer than

compulsory licensing schemes, are anti-trust regulations (concerning tying) and the rules governing the licensing of IPRs (such as patent misuse provisions).

Although tying is illegal under anti-trust laws, the tie-in implicit in a hybrid licence is difficult to evaluate under these laws. American courts use the doctrine of patent misuse to condemn some hybrid licensing arrangements: leading cases in this area rule out some forms of licences.[14] In particular, licensors are prohibited from charging a royalty over the length of the licence that does not decline with the expiration of the patent, *i.e.*, level royalties are illegal. Jurisprudence developed from a number of cases concerning hybrid licensing has led to the following rules:[15]

> 1. In a hybrid agreement in which the royalty obligations for patent and trade secret rights are inseparable...the royalty provisions of the agreement become unenforceable upon expiration of the patent under the *Brulotte* rule...;
>
> 2. In such a case, a licensor may still be eligible for compensation for trade secrets transferred, most likely on the basis of an unjust enrichment theory;[16] and
>
> 3. If a hybrid agreement allocates royalty obligations between patent and non-patent rights, the non-patent royalty obligations may survive patent expiration or invalidity.

These three rules imply that hybrid licensing contracts must be written so as to ensure that patent royalties are distinct from trade secret royalties.[17] Otherwise, the licensor cannot depend on the contract to recover trade secret royalties when the patent expires or if the patent is found invalid. At best, the licensor will receive some court-ordered compensation for transfer of the trade secret. Further, in the *Brulotte* case, the court concluded that "a patentee's use of a royalty agreement that projects beyond the expiration date of the patent is unlawful *per se*."[18]

These judgements mean, as suggested above, that a hybrid licence with level royalties is equivalent to a tying arrangement where, in the view of the courts, the licensor is using market power granted by the patent to gain leverage in the post-expiration market by tying a trade secret licence with a long term to a patent licence which will expire.

This article develops a basic model of the licensing of a process innovation to demonstrate that tying can be strictly socially efficient. Two scenarios are considered; in both, the market structure is initially duopolistic.

In the first situation, the licensor is not a producer of the final good and is considering the prospect of licensing one or both of the producing duopolists. When hybrid licensing is privately efficient -- for example, if neither fixed fees nor the possibility of renegotiation are available -- the present value of licensor, producer, and consumer surplus is typically higher under hybrid licensing than when it is prohibited.[19] However, when the licensor can induce a licensee to accept the same royalty rate under a (tying) hybrid licence as under a (no-tying) patent licence, the sum of surplus is lower with tying, since the longer term of the tying contract is not accompanied by a countervailing reduction in the royalty rate. This result holds, *e.g.*, for a limited set of parameter values (market size, degree of innovation, discount rate) when the licensor is capable of renegotiating licence terms.[20]

The second variant of the model considers a situation similar to existing work on licensing in which the licensor is a producer of the final good.[21] Tying is socially efficient in this case.[22]

II. THE HYBRID CONTRACTING PROBLEM

The problem is based on the choices available to a patent-holder deciding whether to license patented technology and a related trade secret to a potential licensee or licensees. Prohibiting

tying in this context means that the licensor is required to offer a contract involving only the patented technology, that is, the licensee is not forced to pay for the know-how in the trade secret as a condition of acquiring the innovation in the patent.

II(i). ASSUMPTIONS

Know-how

The know-how contained in the trade secret is assumed to be of no value without the patent.[23] The patented technology is a cost-reducing process; the trade secret consists of complementary know-how, unpatented technical information.[24] There is no separate market for know-how. Once given access to the patented innovation, the licensee is capable of discovering the know-how costlessly and immediately. The zero cost of learning the know-how emphasizes the effects of tying: the assumption implies that the tying contract might require the licensee to pay for know-how that could be acquired for free. The trade secret is a "fiction" used to extend the length of the licence.

Legal environment

Patent length is finite ($T < \infty$). Firms have access to the patented technology at zero cost after the T years of the patent term. However, trade secret protection has no fixed length. If contract terms include a royalty on the trade secret, the licensee is obliged to pay R_s indefinitely once the contract is signed.[25]

Contracting

Contracts have the form (F, R_p, R_s).[26] $F \geq 0$, is a fixed fee, independent of the level of output, paid by licensee(s) at the start of the licence. Royalties include a patent royalty that is a payment per unit of output produced over the patent period of $R_p \geq 0$, effective for time t: $0 \leq t \leq T$, and a per-

unit trade secret royalty of $R_s \geq 0$, for $0 \leq t \leq \infty$.[27] Output is fully observable and verifiable: contracts with per-unit royalties can be enforced.

Production and competition

The patented technology and the know-how together reduce unit cost from a high level, c_H, to a low level, c_L, ($c_H > c_L$).[28] Given that development of the know-how is assumed to be costless and immediate, access to the patent implies unit cost can be reduced immediately to c_L. $P = a - Q$ is the inverse demand function with price, P, market size, a, and total quantity, Q. Production is positive under the old technology, *i.e.*, $a > c_H$. Firms produce the same product. Production requires specific assets so the number of firms is fixed in the model: there is no entry. Competition, if any, in the final (production) stage is Cournot.[29]

Incentive to innovate

At $t = 0$, the licensor has discovered the cost-reducing process and obtained a patent. The analysis is not complicated by the decision to innovate. The minimum return available to the innovator in the model is assumed to provide sufficient incentive for innovative activity, in order to focus on the welfare effects from tying other than generating increased profits to encourage research. Since the bargaining power rests entirely with the licensor in this analysis, she will receive at least the per-unit benefit of the innovation, $c_H - c_L$, over the life of the patent, *i.e.*, the present value of the minimum return to licensing is $\frac{1-e^{-rT}}{r}(C_H - C_L)Q$, where Q is the total quantity produced under licence, and r is the discount rate. Imitation of the patented invention by the potential licensee(s) is assumed to be technologically impossible.[30]

Communication and information

Market conditions (demand), the legal environment, the value of the patented innovation, and the value of the trade secret are public knowledge. This assumption rules out the exploitation of any information advantage over competitors that a user of the innovation may gain as a result of lowering cost to an unknown level.

Innovation types

It is important to distinguish between degrees of innovation. Arrow [1962] separates innovations into two classes: an innovation is *drastic* if the monopoly price with the new technology is below the competitive price with the old technology, or *nondrastic,* otherwise. Drastic innovations are such that $\frac{1}{2}(a + C_L) < C_H$ or $\frac{a - C_H}{a - C_L} < \frac{1}{2}$. If the degree of an innovation is $\gamma \equiv \frac{a - C_H}{a - C_L}$, then innovations are drastic for $0 < \gamma < \frac{1}{2}$ and nondrastic for $\frac{1}{2} \leq \gamma < 1$.

II(ii). HYBRID LICENSING WHEN THE LICENSOR IS NOT A PRODUCER

Consider a licensor who is not a producer of the final good, deciding the terms of licences for two potential licensees. The licensor (Firm 0) makes a take-it-or-leave-it contract offer to one or both of these producers (Firms 1 and 2) who must then decide whether to accept. Following these stages, the potential licensees choose quantities in Cournot competition. Excluding any royalties, for $0 \leq t \leq T$, a potential licensee (Firm 1 or 2) produces with unit cost C_H without a licence or C_L with a licence. For $T < t \leq \infty$, after the patent has expired, Firm 1 or 2 can produce with cost C_L, exclusive of royalties.

The licensor must decide whether to license one or both of the potential licensees, *i.e.*, must choose $n = \{1, 2\}$. For a licensing equilibrium, the licensor chooses n, F, R_p, and R_s to maximize the present value of profits, V_0, subject to the relevant constraints.[31] A potential

licensee must choose between accepting (H) and not accepting (N) a hybrid contract and then set production levels accordingly.[32] Firm i receives returns of V_i^{HN}, $i = \{1, 2\}$, if firm i accepts a licence while the other, firm j, $j \neq i$, does not.

There are two participation constraints relevant for the licensor's decision: Constraint 1, $V_i^{HN} \geq V_i^{NN}$, such that a single firm would receive as much with a licence as without it given that the other firm is not licensed;[33] and a constraint such that a firm would accept a licence when the other firm had accepted a licence, *i.e.*, $V_i^{HH} \geq V_i^{NH}$, Constraint 2. Both constraints are required for a unique equilibrium when $n = 2$. If it is optimal for the innovator to license only one firm, only the first constraint matters.[34] With an exclusive licence, a producing firm would receive V_i^{HN} so, for $n = 1$, the single participation constraint is $V_i^{HN} \geq V_i^{NN}$. Along with non-negativity constraints for production quantities, royalties, and the licensor's returns at her preferred contract, the licensor's choice of royalties must not be higher than the cost difference, *i.e.*, $R_p + R_s \leq C_H - C_L$. If royalties were higher than this level, a licensee would prefer to abandon the new technology in favour of the old technology.[35]

Proposition 1

In equilibrium, with a non-producing licensor offering licences to one or both producers, licences are based only upon a fixed fee or a combination of a fixed fee and a patent royalty; there is no equilibrium with hybrid licensing.

Proof and Discussion of Proposition 1

For a drastic innovation, $0 < \gamma < ½$, a single licensee can become a monopolist: the other firm is unable to compete and exits the market for $0 \leq t \leq T$. The licensor cannot do better than to license a monopolist and so creates one (during the patent period) with an exclusive licence, extracting

the additional returns from the licensee. Given that it is not optimal for the licensor to distort the output choice of the licensee by charging a per-unit royalty, the licensee sets a fee arising from the participation constraint when $n = 1$, $V_i^{HN} \geq V_i^{NN}$, or:

$$\frac{1-e^{-rT}}{r}\left(\frac{a-C_L}{2}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a-C_L}{3}\right)^2 - F \geq \frac{1-e^{-rT}}{r}\left(\frac{a-C_H}{3}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a-C_L}{3}\right)^2 \tag{1}$$

and so, from the maximization of V_0 subject to Constraint 1, the licence has the form:[36]

$$n = 1, F = \frac{1-e^{-rT}}{r}\left(\frac{a-C_L}{2}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a-C_H}{3}\right)^2, R_p = 0, R_s = 0 \tag{2}$$

For a nondrastic innovation, the licensor is not able to create a monopolist with an exclusive licence. For relatively trivial innovations such that $¾ \leq \gamma < 1$, the licensor offers a licence with only a fixed fee to both licensees, capturing the returns to the Cournot firms from the decrease in unit costs. From the maximization of V_0 subject to Constraint 2, the licence is:

$$n = 2, F = \frac{1-e^{-rT}}{r}\left(\frac{a-C_L}{3}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a-2C_H+C_L}{3}\right)^2, R_p = 0, R_s = 0. \tag{3}$$

The licence term is not extended beyond the patent term by licensing; there is no tying. With a fixed fee, compensation for the innovation is settled at the start of the patent period. There are no distortionary royalties: the patent-holder has simply used the freedom to contract provided by the patent grant to extract the maximum reward from the market as a lump sum.[37]

For the remaining innovations: $½ \leq \gamma < ¾$. These innovations provide a cost reduction that is more than trivial, yet less than drastic. For these substantial innovations, the maximization of V_0, given by:

$$\frac{1-e^{-rT}}{r}\left(\frac{a-C_L-R_p-R_s}{3}\right)2\left(R_p+R_s\right) + \frac{e^{-rT}}{r}\left(\frac{a-C_L-R_s}{3}\right)2R_s + 2F \tag{4}$$

when $n = 2$, subject to Constraint 2, $V_i^{HH} \geq V_i^{HN}$, or:

$$\frac{1-e^{-rT}}{r}\left(\frac{a-C_L-R_p-R_s}{3}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a-C_L-R_s}{3}\right)^2 - F \geq \frac{1-e^{-rT}}{r}\left(\frac{a+C_L-2C_H+R_p+R_s}{3}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a-C_L+R_s}{3}\right)^2 \tag{5}$$

yields a licence with both a fixed fee and a patent royalty:

$$n = 2, F = \frac{1-e^{-rT}}{r}\left(\frac{a - C_L - R_p}{3}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a - 2C_H + C_L + R_p}{3}\right)^2, R_p = \frac{4(C_H - C_L) - (a - C_L)}{6}, R_s = 0 \qquad (6)$$

The licensor would like to have relatively high royalty rates since a higher royalty pushes the output level chosen by the licensees closer to the monopoly output.[38] Once the licensees have been pushed as close to the monopoly level of output as is feasible (or desirable, from the viewpoint of the licensor), the licensor could then set the fixed fee to extract any remaining surplus from the use of the innovation. But a higher royalty increases the potential licensee's opportunity profit of operating without a licence while his competitor is constrained to pay royalties. This represents a rather unique feature of the licensor's problem: the outside opportunity of a licensee depends upon the licensor's choice of R_p. An increase in opportunity profit (from a higher R_p, chosen to induce an output closer to the monopoly output) implies a reduction in the amount that a licensee would be willing to pay as a fixed fee. Thus, in choosing the terms of the licence, the licensor must balance the marginal benefit of having a higher royalty against the marginal reduction in licensing revenues (from a reduced fixed fee) that setting a higher royalty rate involves. This trade-off implies that the royalty rate that achieves the monopoly output is too high from the licensor's point of view: this high royalty diminishes the fixed fee that can be extracted more than is optimal for the licensor.

The licensor does not offer a tying contract in the licensing equilibria presented above. Potential licensees place too much value on the profits they can earn in the post-patent period such that they are unwilling to contract for the trade secret section of the hybrid licence unless the licensor is willing to reduce the royalty rate to a low level; however, the licensor places relatively too much value on revenues received during the patent period to offer a royalty rate low enough

to induce the licensees to accept the hybrid licence. Of the licences with $R_p = 0$, the hybrid licence that would provide the greatest returns for the licensor has the form:[39]

$$n = 2, F = \frac{1}{r}\left(\frac{a - C_L - R_s}{3}\right)^2 - \frac{1 - e^{-rT}}{r}\left(\frac{a - 2C_H + C_L + R_s}{3}\right)^2 - \frac{1 - e^{-rT}}{r}\left(\frac{a - C_L + R_s}{3}\right)^2, R_p = 0, R_s = \frac{4(1 - e^{-rT})(C_H - C_L) - (a - C_L)}{6}. \quad (7)$$

The licensor would be charging level royalties with a hybrid licence as in (7): a zero patent royalty implies that there is no decline in per-unit payments at T with patent expiration. The revenues from such a licence are lower than those from the patent-only licence, as in (6).[40]

The licensing equilibrium does not yield a hybrid.[41] Two refinements, discussed below, deliver hybrid licensing for wider ranges of the parameters: the possibility of renegotiating the licences after an initial round of offers, and the unavailability of fixed fees.

Renegotiation

The constraints in the problem above arose from a subgame perfect Nash equilibrium to a two-stage game. Contract offers are made and accepted or rejected in the first stage; production occurs in the second stage with cost structures conditional upon the licensing in the first stage. There is no renegotiation; hence contracts are binding on a licensor and a licensee even when it might be in the interest of both to renegotiate. If renegotiation is possible, then the licensor may be able to induce licensees to accept a hybrid licence.

To obtain this result, a potential licensee must believe that if he rejects the initial licence offer then he will be placed at a competitive disadvantage as the licensor will offer the other firm a (renegotiated) favourable licence. In particular, the other licensee will be offered a zero-royalty contract. These beliefs correspond to the wary beliefs discussed by McAfee and Schwartz [1994]. There are three stages to this game: the first round of contract offers, renegotiation if needed, and

finally production of the final good. The initial choice of a potential licensee is to accept or reject the offered licence. Renegotiation does not occur in equilibrium.

For drastic innovations, exclusive licensing is the preferred outcome for the licensor. For nondrastic innovations the licensor would prefer to licence both firms and so she would use the threat of renegotiation to induce both potential licensees to accept the hybrid licence that provides her with the highest returns.

If one firm accepts while the other rejects, the firm that accepts will renegotiate contract terms with the licensor. For $n = 1$, the exclusive licence that is the threat contains a fixed fee but no output royalties.[42]

Two pressures shape the equilibrium in which a licence for a nondrastic innovation is accepted by both producing firms. For each of the potential licensees there is the hope of gaining a competitive advantage by accepting a licence while the other rejects -- thus becoming the firm that receives a favourable exclusive licence -- and the fear of being placed at a competitive disadvantage by rejecting the current offer, leading the licensor to renegotiate with the other firm. This game shares some features with a prisoner's dilemma game: although both licensees might be better off if they both rejected the initial licence offered by the licensor, and simply waited to produce in the post-patent period, in equilibrium both licensees accept the licence offer of the licensor (as derived below).

Proposition 2

If renegotiation is possible and the potential licensees have wary beliefs, the equilibrium licence for nondrastic innovations is a hybrid licence with level royalties.

Proof and Discussion of Proposition 2

The initial offer of the licensor is accepted by both firms in equilibrium. The parameter boundaries for the equilibrium licences are depicted in Figure 1. (REFER TO FIGURE 1)

If innovations are drastic, as in Region 1 of Figure 1 where $0 < \gamma < 1/2$, the licensor extracts from a licensee the difference between the monopoly profits available with the licence over the patent term and the profits that would have accrued to the licensee under Cournot competition with unit cost c_H. The licence is:

$$n = 1, F = \frac{1 - e^{-rT}}{r}\left(\frac{a - C_L}{2}\right)^2, R_p = 0, R_s = 0. \tag{8}$$

For nondrastic innovations, the licensor cannot create a monopoly during the patent term: in equilibrium, both producing firms are licensees. The licensor uses per-unit royalties to alter the cost structure of the industry and thus an equilibrium licence specifies a royalty rate. It is not in the licensor's interest to have both a patent royalty and a trade secret royalty in the hybrid licence and so $R_p = 0$. The licensor chooses F and R_s to maximize:

$$V_0 = \frac{1}{r}\left(\frac{a - C_L - R_s}{3}\right)2R_s + 2F \tag{9}$$

subject to the constraint that the licensee makes as much with the licence as without it. Without a licence, a potential licensee faces c_H while the other licensee has a lower unit cost and pays no output royalties under the threatened exclusive licence for the other licensee. This outside opportunity is not dependent on the level of per-unit royalty chosen by the licensor for the two-firm licence, unlike the situation in the basic game described at the start of this section: a higher royalty rate does not increase the opportunity profits of rejecting the licence. In selecting a royalty rate, the licensor need only consider the maximization of royalty revenues -- raising the royalty rate increases the rate per unit but decreases the number of units of output chosen in

equilibrium by the licensees -- subject to the participation constraint. The licensor does not need to evaluate the effect of the royalty rate on the returns to rejecting the licence. The participation constraint is given by:

$$\frac{1}{r}\left(\frac{a-C_L-R_s}{3}\right)^2 - F \geq \frac{1-e^{-rT}}{r}\left(\frac{a+C_L-2C_H}{3}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a-C_L}{3}\right)^2 \tag{10}$$

For substantial innovations, nondrastic innovations such that $1/2 \leq \gamma < 3/4$, the licensor can use the royalties in the hybrid licence to push the licensees to produce, jointly, the level of output that a monopolist with unit cost c_L would produce, extracting any additional surplus by means of a fixed fee. The licence for substantial innovations is:[43]

$$n = 2,\ F = \frac{1}{r}\left(\frac{a-C_L}{4}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a+C_L-2C_H}{3}\right)^2 - \frac{e^{-rT}}{r}\left(\frac{a-C_L}{3}\right)^2,\ R_p = 0,\ R_s = \tfrac{1}{4}\left(a-C_L\right). \tag{11}$$

However, for this licence to satisfy the condition that $F \geq 0$, it must be the case that:[44]

$$\gamma(1-\gamma)\left(1-e^{-rT}\right) > \tfrac{7}{64},\ \text{or}\ e^{-rT} < \frac{64(1-\gamma)-7}{64(1-\gamma)}. \tag{12}$$

Thus, the licence in (11) is only feasible in Region 2 of Figure 1 where $1/2 \leq \gamma < 3/4$ and the discount rate is high enough for the condition in (12) to be satisfied. If this condition is not satisfied, *i.e.*, for the remaining substantial innovations, the licence is:

$$n = 2,\ F = 0,\ R_p = 0,\ R_s = a - C_L - \left[\left(1-e^{-rT}\right)\left(a+C_L-2C_H\right)^2 + e^{-rT}\left(a-C_L\right)^2\right]^{\frac{1}{2}} = a - C_L - \left[9rV^{NE}\right]^{\frac{1}{2}} \tag{13}$$

where V^{NE} is the return to producing without a licence while the other firm has an exclusive licence from renegotiating with the licensor. This licence is the equilibrium contract for the parameter values in Region 3 of Figure 1.

For trivial innovations, $3/4 \leq \gamma < 1$, the licensor is unable to induce the licensees to produce the monopoly output. The highest royalty rate available to the licensor is simply the decrease in unit costs conferred by the new technology. The equilibrium licence is:

$$n = 2,\ F = \frac{1}{r}\left(\frac{a-C_H}{3}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a+C_L-2C_H}{3}\right)^2 - \frac{e^{-rT}}{r}\left(\frac{a-C_L}{3}\right)^2,\ R_p = 0,\ R_s = C_H - C_L. \tag{14}$$

For $F \geq 0$, the discount rate must be sufficiently high such that:

$$e^{-rT} < \frac{3\gamma - 1}{4\gamma}. \tag{15}$$

The licence in (14) is the equilibrium contract for parameter values as in Region 4 of Figure 1. For the remainder of trivial innovations, Region 5, where the discount rate is low enough that the condition in (15) fails to hold, the equilibrium licence is as given in (13): a contract with a royalty on the trade secret and no fixed fee.

For nondrastic innovations, the equilibrium to the licensing game when tying is permitted involves a hybrid royalty with level royalties.

Proposition 3

When the equilibrium licence is a hybrid licence with royalties that are lower than the corresponding patent royalty were tying prohibited, *i.e.*, when the conditions in (12) and (15) are not satisfied, permitting hybrid licensing is socially more efficient than its prohibition.

Proof and Discussion of Proposition 3

The prohibition of tying amounts to requiring the licensor to offer a licence for the patented technology alone. The assumption that the development of the know-how is costless and immediate upon acquisition of the patented technology implies that there would be no separate licence for the know-how with $R_s > 0$. If tying is prohibited, then the licensor chooses F and R_p to maximize licensing returns:

$$V_0 = \frac{1 - e^{-rT}}{r}\left(\frac{a - C_L - R_p}{3}\right)2R_p + 2F \tag{16}$$

subject to:

$$\frac{1 - e^{-rT}}{r}\left(\frac{a - C_L - R_p}{3}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a - C_L}{3}\right)^2 - F \geq \frac{1 - e^{-rT}}{r}\left(\frac{a + C_L - 2C_H}{3}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a - C_L}{3}\right)^2 \tag{17}$$

For substantial innovations, $1/2 \leq \gamma < 3/4$, the equilibrium licence when tying is prohibited is:

$$n = 2, F = \frac{1-e^{-rT}}{r}\left(\frac{a-C_L}{4}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a+C_L-2C_H}{3}\right)^2, R_p = \tfrac{1}{4}(a-C_L), R_s = 0. \quad (18)$$

This licence is feasible for Regions 2 and 3 in Figure 1. Note that in Region 2, the royalty rate of $\frac{1}{4}(a - C_L)$ which is paid only during the patent term under the licence in (18) is the same royalty rate that is paid forever under the hybrid licence as in (11). For trivial innovations, the royalty rate must not exceed the decrease in cost from the patented innovation, and so the equilibrium licence when $3/4 \leq \gamma < 1$ is:

$$n = 2, F = \frac{1-e^{-rT}}{r}\left(\frac{a-C_H}{3}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a+C_L-2C_H}{3}\right)^2, R_p = C_H - C_L, R_s = 0 \quad (19)$$

which includes the same royalty rate as the hybrid licence of (14); however, the hybrid licence extends indefinitely.

The present value of the sum of licensor, producer and consumer surplus under the hybrid licences (tying permitted) of (11) and (14) is lower than the present value of the sum of surplus under the patent-only licence (tying prohibited).[45] This result arises since there is no countervailing social benefit derived from extending the length of the licence: the royalty rate is not lower under the hybrid licence to compensate for the greater period during which royalties are paid. In Figure 1, the parameter values for the hybrid licences that reduce efficiency are contained by Regions 2 and 4.

Using a common social discount factor, that is, abstracting from distributional issues to consider efficiency alone, the present value of the sum of licensor, producer, and consumer surplus is higher when tying is permitted than when it is prohibited for equilibria that generate hybrid licences as in (13). If the licensor wishes to smooth the royalty stream -- instead of charging a patent royalty followed by a zero royalty -- by decreasing the royalty rate during the

patent period and increasing post-patent royalties to compensate, then efficiency is increased by permitting the hybrid licences that accomplish this smoothing.[46]

Efficiency under the hybrid licence, as in (13), is greater than efficiency under the patent-only licences, as in (18) or in (19). For the parameter values for which this hybrid licence obtains, the hybrid royalty rate is lower than the royalty rate in the corresponding patent-only licence. Thus, although the hybrid licence extends the length of time over which royalties must be paid, the reduction in rate over the patent term is sufficient to generate the efficient ITL result.[47] This result holds for Regions 3 and 5 of Figure 1. To put the efficiency results into perspective, when the discount rate is 3% and the patent term is 17 years, the discount factor is: $e^{-rT} = 0.6$. For this discount factor, for all degrees of nondrastic innovations, permitting tying is more efficient than its prohibition.

Note that the primary feature that distinguishes the hybrid licences that reduce social surplus, in contrast to those that enhance social efficiency, is the presence of a fixed fee.[48] Given that the opportunity returns of the potential licensees do not depend on the royalty rate chosen by the licensor in her optimal contract, for a sufficiently high value of r, the licensor retains the same royalty rate in the tying hybrid licence as the patent-only licence but reduces the fixed fee to compensate for the extension of licence length, holding the licensees to their opportunity profits. The efficient ITL result depends on a reduction in royalty rate. In this version of the model, where the licensor can threaten a potential licensee who rejects a licence with the prospect of competing against a licensee who accepts a contract and then renegotiates a licence with a fixed fee and zero royalties, a sufficiently low discount factor implies that it is the fixed fee that is reduced with the extension of the length of the licence, not the royalty rate. If this compensatory

shift in the fixed fee is unavailable, the licensor must reduce the royalty rate to secure a hybrid licence, provided her choice of contract terms is constrained by the opportunities of a potential licensee. To demonstrate this point, the next results are derived under conditions where fixed fees not available and there is no possibility of renegotiation.

Fixed fees unavailable

Empirical evidence suggests that the majority of intellectual property licences have payment schedules that are based on fixed fees, royalty rates, or both. The strategic licensing structure developed above provides examples of parameter values under which the licensor selects fixed fees, or royalty rates, or a combination, *e.g.*, fixed fees are used for drastic innovations. The strategic choice of royalty rates to influence, or refrain from influencing, the marginal costs of the licensees is not the only motivation for contracts with royalties, however. In addition to these situations, there are circumstances in which a licensor would prefer, or be constrained to use, per-unit royalties in a licence as opposed to offering a licence with a fixed fee. Examples include demand uncertainty, imperfect information, and the possibility of imitating innovation. Although these conditions are not considered explicitly in the analysis that follows, a restricted model that arises from confining contract terms to per-unit output royalties will serve to further illustrate the way in which the hybrid licenses rejected by the courts can reach the efficient ITL outcome and also serve to reiterate that there is a basis for the concerns that courts have expressed regarding a licensor's use of a tying contract to adversely affect efficiency in the post-patent period.

Some contracts do not, in fact, include fixed fees.[49] One common explanation is that royalties are preferred to fixed fees due to risk-sharing in the face of uncertainty: an innovator, or licensee, may be unwilling to bear the risk associated with receiving, or paying, a fixed fee

based on the expected value of the transfer of the innovation, although a fixed fee with a payment schedule dependent on future realizations of demand could resolve this problem in some cases. For other discussions of the choice of licence terms see, for example, Contractor [1981] who suggests that per-unit royalties might be preferred by licensees over lump sum fees because "they can be paid out of profits and because the licensor would continue to have an interest in the licensee's ability to produce;[50] Gallini and Wright [1990] who consider the impact on licences of superior information held by the licensor about the value of the innovation and the ability of the licensee to imitate or "invent around" patented innovations, deriving conditions under which an innovator would prefer output royalties to a fixed fee; or Macho-Stadler *et al.* [1993] who suggest that "the inclusion of royalties in the contract is a way of involving the licensor in the licensee's use of the patent...[that] reduces the moral hazard temptations of not transferring all the know-how (which by nature is difficult to measure)."[51]

While there are a number of behavioural or environmental conditions that would make fixed fees unattractive to a licensor, including the theoretical structure that would incorporate these conditions would add complexity to the model without producing much additional insight. In order to illuminate the efficiency effects of the hybrid licensing that has been observed, the next results will be derived by simply restricting $F = 0$.

The remainder of this section proceeds with a modified set of contract possibilities: licences have the form ($F = 0$, $R_p \geq 0$, $R_s \geq 0$) and cannot be renegotiated after acceptance.

Proposition 4

In equilibrium, the licence between a non-producing licensor and two Cournot competitors is a hybrid licence with level royalties ($R_p = 0$) for both licensees, when fixed fees are not chosen or not available.

Proof and Discussion of Proposition 4

The licensor will licence at least one firm since she makes nothing otherwise.[52] For nondrastic innovations, a firm that is not licensed is still able to compete during the patent period: the licensor does better by licensing both producing firms. For more drastic innovations, if the licensor charged a very low royalty to one firm, it could become a monopoly. However, the returns from a licence to one firm with a positive royalty that is low enough to create a monopoly during the patent term are smaller than from licensing both firms: the royalty that allows or creates a monopoly is too low and the quantity too limited to outweigh the benefits of the larger quantity and higher royalty available when licensing both firms. As a result, the relevant constraint for the licensor's maximization problem is $V_i^{HH} \geq V_i^{NH}$ (*i.e.*, Constraint 2 as given in Equation (5), page 11, but with $F = 0$, as in Equation (20), page 20) implying that the returns to a potential licence from accepting a licence must be greater than rejecting, given that the other firm has accepted. The licensor will choose either a contract with solely a patent royalty $(R_s = 0)$ or a hybrid royalty $(R_p = 0)$; it is not optimal for the licensor to offer a license with both $R_p > 0$ and $R_s > 0$. Recall that $(R_p = 0)$ implies a level royalty since royalty payments do not decline at T with the expiration of the patent. Table 1 presents the licence terms when tying is permitted.

(REFER TO TABLE 1 AND FIGURE 2)

When Constraint 2 is not binding, *i.e.*, for drastic innovations when the discount factor is sufficiently low, the licensor prefers $R_s = \frac{1}{2}(a - C_L)$. Given that V_0 is the discounted sum of royalty revenues, the licensor makes the same kind of assessment as any other seller with some market power: decreasing the royalty results in a larger number of units of output for which the royalty can be collected but decreases the returns on the infra-marginal units. This royalty rate can be obtained for drastic innovations when the discount rate is sufficiently high. In Figure 2, this region is in the lower left corner of the diagram in region 1. Outside of the boundary of this region, Constraint 2 is binding on the licensor's choice of the hybrid royalty rate.

When Constraint 2 is binding, the licensor can charge only that royalty that leaves the potential licensee indifferent between accepting the license and producing without a license while his competitor is constrained to pay royalties. In this case, as in the first version of the model presented above, reducing the royalty has two effects: it increases the number of units upon which the royalty is paid and makes producing without a licence less attractive.

For drastic innovations with a high discount factor or for very drastic innovations (very low γ), with an intermediate or higher discount factor, a sufficiently low royalty rate would create a monopoly during the patent period if only one of the producing firms accepted the licence.[53] Under these conditions, Constraint 2 is:

$$\frac{1}{r}\left(\frac{a - C_L - R_s}{3}\right)^2 \geq 0 + \frac{1 - e^{-rT}}{r}\left(\frac{a - C_L + R_s}{3}\right)^2 \tag{20}$$

For this region of the parameter set – region 2 in Figure 2 – the licensor can charge a royalty of $R_s = \frac{1-(e^{-rT})^{0.5}}{1+(e^{-rT})^{0.5}}(a - C_L)$ to both firms that, as the discount factor approaches 1/9, approaches the unconstrained royalty, which is $\frac{1}{2}(a - C_L)$.

For less drastic innovations, Constraint 2 has the form:

$$\frac{1}{r}\left(\frac{a-C_L-R_s}{3}\right)^2 \geq \frac{1-e^{-rT}}{r}\left(\frac{a-2C_H+C_L+R_s}{3}\right)^2 - \frac{e^{-rT}}{r}\left(\frac{a-C_L+R_s}{3}\right)^2 \tag{21}$$

For nondrastic innovations, region 4 in Figure 2, Constraint 2 as given by (21) is binding and the licensor charges $R_s = \frac{(1-e^{-rT})(a-C_H)(C_H-C_L)}{(1-e^{-rT})(a-C_H)+e^{-rT}(a-C_L)}$. For slightly more drastic innovations, this royalty results where the other royalties discussed above are not feasible, *i.e.*, in region 3 of Figure 2.

Proposition 5

Extending licence length by the use of a hybrid licence is efficient if the equilibrium hybrid royalty rate with tying permitted is sufficiently smaller than the equilibrium royalty rate for a patent-only licence with tying prohibited.

Proof and Discussion of Proposition 5

When tying is prohibited, the licensor would select $R_p = C_H - C_L$ for nondrastic innovations and $R_p = ½(a - C_L)$ for drastic innovations.

To evaluate efficiency, consider the sum of surplus, $W \equiv CS + V_0 + V_1 + V_2$, where CS is the present value of consumer surplus and V_k is the present value of producer or innovator surplus, $k = 0, 1, 2$, comparing this welfare measure with the hybrid licence, $W(R_s)$ if tying is permitted, to the measure with the patent-only licence, $W(R_p)$ if tying is prohibited.

When the licensor chooses a hybrid royalty rate that is smaller than the corresponding patent-only royalty rate, the present value of social surplus is higher when extending the licence length through a hybrid licence is permitted. This result occurs for most values of γ and e^{-rT} and arises from the effects discussed earlier in the paper: a lower royalty rate during the patent period decreases the distortion ensuing from the use of per-unit royalties. To achieve this lower royalty rate during the patent period without reducing the rents that accrue to the patent-holder, the length

of the licence needs to be increased. Although royalties are paid for a longer period, the increase in surplus during the patent period generally outweighs the decrease in the post-patent period.

For nondrastic innovations and most drastic innovations, with tying permitted and hence trade secret royalties possible, the licensor can smooth the royalty stream, decreasing the royalty during the patent term and increasing the post-patent royalties to compensate. There is a private incentive to smooth royalties and efficiency is increased by permitting the hybrid licences that can accomplish this smoothing.[54] Prohibiting tying for most innovations penalizes the patentee without improving the lot of the licensee or of consumers, under the conditions of the model.

There are some conditions under which permitting hybrid licences reduces efficiency. These conditions are represented in the shaded areas of Figure 2, that is, in region 1 and a small area within region 3. In the shaded area, the hybrid royalty rate is not sufficiently smaller than the patent-only rate to generate the ITL result. For drastic innovations and a low discount factor, region 1, the licensor would set a patent royalty of $\frac{1}{2}(a - C_L)$ if tying were prohibited; if tying were permitted, the licensor would charge a royalty of $R_s = \frac{1}{2}(a - C_L)$. The tie-in would allow the licensor to charge the same high royalty rate forever. The licences for which this observation applies are those for which the participation constraint did not bind on the licensor's choice of hybrid royalties. This result is intuitively appealing, at least: for the licensor to be able to set the same royalty after the patent period as during it, the licensee must not place much value on profits received after T. If the licensee is more concerned about profits after T, the innovation must be correspondingly more drastic for the constraint not to bind.

For $e^{-rT} > 1/9$, the participation constraint always binds. For the small area, in region 3, in which the constrained hybrid royalty would reduce efficiency, as e^{-rT} approaches zero, the

hybrid royalty approaches $c_H - c_L$. But since innovations in this small area are drastic, this royalty rate is equal to or very slightly smaller than the patent-only royalty of $\frac{1}{2}(a - c_L)$.[55] As e^{-rT} increases from zero the hybrid royalty declines but, for a small area within the feasibility region of this particular royalty, there is not a sufficient reduction in royalties to generate the smoothing effect. As e^{-rT} increases further, the hybrid royalty declines so that for most of region 3, the smoothing effect is large enough to give rise to the efficient ITL outcome.

The standard argument in favour of tying relies on the idea that there is an upper bound to the amount that a seller can extract from a buyer, *i.e.*, that the buyer evaluates the package of goods offered by the seller and thus an increase in the effective price of one good in the package must be matched by a decrease in the effective price of another. The optimal patent length argument of Tandon [1982] or Gilbert and Shapiro [1990] involves holding constant the return to the patentee while extending the period of compensation in order to secure a reduction in price. The argument in this paper would suggest that for efficiency gains from permitting tying, it is necessary that there be some reduction in the "price" or royalty rate during the patent period, although it is not necessary to fix the returns to the licensor to obtain this result. However, without a sufficient reduction in royalty rate, there can be a reduction in efficiency: royalty rates can be "too high for too long" from a social perspective. The examples developed here suggest that privately chosen per-unit royalties will increase efficiency, unless innovations are drastic and the discount rate is high.[56]

II(iii). HYBRID LICENSING WHEN THE LICENSOR IS A PRODUCER

Consider an innovator who produces the final good for the market: the licensor in this situation has two objectives: *(i)* to obtain the highest return on the technology through the licence, and

(ii) to change the relative cost structure in the industry through setting royalty rates. Any per-unit royalty would be an additional component of unit cost for the licensee. The licensor could exploit the leadership position imparted by the innovation by setting contract terms to its advantage in ensuing competition.[57] In the production stage the two firms compete in quantities (Cournot) but in the pre-production (or contract-setting) stage the licensor can act as a Stackelberg leader since equilibrium quantities depend on contract terms.[58]

If the licensor, who receives V_1, decides to offer a licence, she will choose a licence, (F, R_p, R_s), to maximize the present value of profits which includes: the present value to producing with unit cost C_L while the competitor has unit costs of C_L plus any royalties (the first two terms in equation (22)); and the present value of licensing returns which includes royalty revenues during the patent period and the post-patent period, and the fixed fee (the final three terms). In a licensing equilibrium, the licensor's returns are given by:

$$V_1^H = \frac{1-e^{-rT}}{r}\left(\frac{a-C_L+R_p+R_s}{3}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a-C_L+R_s}{3}\right)^2 + \frac{1-e^{-rT}}{r}\left(\frac{a-C_L-2R_p-2R_s}{3}\right)\left(R_p+R_s\right) + \frac{e^{-rT}}{r}\left(\frac{a-C_L-2R_s}{3}\right)R_s + F. \tag{22}$$

Along with non-negativity constraints for the licence terms, the licensor's choice of contract terms must satisfy $V_1^H \geq V_1^N$ where:

$$V_1^N = \frac{1-e^{-rT}}{r}\left(\frac{a+C_H-2C_L}{3}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a-C_L}{3}\right)^2 \tag{23}$$

for nondrastic innovations; and, for drastic innovations:

$$V_1^N = \frac{1-e^{-rT}}{r}\left(\frac{a-C_L}{2}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a-C_L}{3}\right)^2. \tag{24}$$

In addition, the optimal licence cannot violate the participation constraint, $V_2^H \geq V_2^N$, which for nondrastic innovations has the form:

$$\frac{1-e^{-rT}}{r}\left(\frac{a-C_L-2R_p-2R_s}{3}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a-C_L-2R_s}{3}\right)^2 - F \geq \frac{1-e^{-rT}}{r}\left(\frac{a+C_L-2C_H}{3}\right)^2 + \frac{e^{-rT}}{r}\left(\frac{a-C_L}{3}\right)^2. \tag{25}$$

Proposition 6

For drastic innovations, $0 < \gamma < ½$, the licensor would choose not to offer a licence to the competing firm. For nondrastic innovations, $½ \leq \gamma < 1$, a producing innovator can extract all additional returns from the use of an innovation from a Cournot competitor through either a patent-only licence and a hybrid licence and thus is indifferent to the different licence lengths represented by these two forms of licence.

Proof and Discussion of Proposition 6

If the innovation is drastic, the licensor would choose not to offer a licence, preferring to earn monopoly profits for the duration of the patent period, since the other firm is unable to compete using the old technology. For nondrastic innovations, from the maximization of V_1^H subject to $V_2^H \geq V_2^N$, contract terms when tying is permitted are any combination of royalties such that $R_p \geq 0$, $R_s \geq 0$, and $V_2^H = V_2^N$.[59] Define $V_1^H = \Phi_1$, where Φ_1 is a constant equal to the maximized value of Firm 1's profits with a hybrid licence. The licensor uses the contract to extract all additional profits available to the licensee from using nondrastic innovations: **any** combination of royalties such that the licensee is held to V_2^N (and hence the licensor receives Φ_1) will be optimal for the licensor.[60] The extremes of the contract solutions are: a sole patent royalty, $F = 0$, $R_p^* = C_H - C_L$, $R_s = 0$, and a level royalty, $F = 0$, $R_p = 0$, $R_s^* = ½(a - C_L) - ½(9rV_2^N)^{½}$. Note that in this situation, unlike for the previous models, licences in which both $R_p > 0$ and $R_s > 0$ could be optimal for the licensor, *i.e.*, if tying is permitted the licensor would not necessarily prefer level royalties (which would imply $R_p = 0$). Note also that the licensor does not choose a positive fixed fee since she wishes to affect the cost structure of the licensee.

The indifference of the licensor to the type of royalty arises from the (simplifying) assumptions of the model, *i.e.*, linear demand, Cournot competition, and common discount rates for licensor and licensee. If the licensor is not also a producer of the final good, as in the previous models, then she is only concerned with licensing revenues and may be willing to reduce the higher royalties in the patent period by choosing a level royalty provided returns in the post-patent period are sufficiently valuable: if there is tying, the royalty rate is lower during the patent period when e^{-rT} is sufficiently high. When the licensor is also a producer of the final good, she takes into account the impact of royalties on licensing revenues and on producing revenues. It is possible for per-unit royalties to impact these two revenue sources in opposing directions. When the model is constructed such that licensor and licensee make the same trade-off between patent period returns and post-patent period returns (common discount rate) and the per period returns of the licensor increase and those of the licensee decrease at the same rate with increasing royalties (linear demand and Cournot competition), then the returns of the licensor, constrained by the licensee's participation constraint, will be the same regardless of the degree to which the royalty burden is shifted to the post-patent period by the shift from patent royalties to trade secret royalties.

For a non-producing licensor, as we have seen, licensing revenues are increasing in R_s when it is possible to hold opportunity profits of the licensee constant. With the royalty burden shifted to the trade secret and away from the patent, returns during the patent period may be lower but this decrease is more than offset by the increase in returns in the post-patent period. When it is not possible to hold the opportunity profits of the licensee constant, as in the first version of the model where a licensee rejecting a license may confront a competitor who pays royalties,

raising the royalty rate increases the opportunity profits of rejecting the licence. This effect is most pronounced in the post-patent period and so licensing revenues are decreasing in R_s, *ceteris paribus*, when the licensor must consider the impact of royalties on a competitor who pays no royalties. This impact forms part of the constraint on the licensor's choice of royalties when she does not produce the final good; when she is a producer, this impact enters directly into her maximization problem since she is the competitor who is not paying royalties.

To summarize, when the licensor is not a producer either the opportunity profits of a potential licensee depend on the royalty choice of the licensor (and so $R_p > 0$ and $R_s = 0$ in equilibrium) or the opportunity profits of the licensee are independent of the royalty choice of the licensor (and so $R_p = 0$, and $R_s > 0$).

Both of these effects arise when the licensor is also a producer of the final good, although they enter into the licensor's problem in a different way. The opportunity profits of the licensee are not dependent on the royalties chosen by the licensor; hence, licensing revenues are increasing in R_s, holding V_2^H constant (equal to V_2^N). Tying provides the licensor with greater freedom to select licence terms: not only can she balance a lower royalty rate (lower distortion) with greater quantity produced under licence against a higher royalty rate collected on a smaller quantity during the patent period, but she can also perform this trade-off in the post-patent period, holding the present value of a licensee's returns constant. But a lower distortionary royalty rate has an additional effect beyond simply increasing the quantity produced under licence if the licensor is also a producer of the final good: the increased quantity produced by the competitor under a licence with a lower royalty rate diminishes the returns the licensor receives from producing and selling the good herself. Thus, the present values of returns from the sale by the licensor of the

final good are decreasing in R_s, holding V_2^H constant. Shifting the burden of royalties away from the patent and onto the trade secret reduces the royalty rate in the patent period, decreasing the costs of the competitor, increasing his equilibrium quantity and thus diminishing the returns to the licensor from production. The gains in production returns that the licensor receives in the post-patent period from a higher trade secret royalty do not outweigh the losses incurred in the patent period from the corresponding lower total royalty rate.[61]

In the model presented above, the increase in licensing returns from a higher R_s (post-patent gains dominating patent period losses) are exactly offset by the decrease in production returns (patent period losses exceeding post-patent gains): the combined result of the assumptions is that the two effects cancel out. In contrast, if the discount rate of the producing licensor is lower than the discount rate of the licensee, then the equilibrium licence for nondrastic innovations is simply a hybrid licence with level royalties.[62]

Proposition 7

With common discount rates, social efficiency can be higher when tying is permitted than when it is prohibited. It is highest when tying is permitted and the equilibrium licence, between a licensor who is a producer of the final good and a single Cournot competitor, is a hybrid licence with level royalties.

Proof and Discussion of Proposition 7

When tying is prohibited the licensor chooses contract terms with the additional constraint that $R_s = 0$. Licence terms when tying is not permitted are $F = 0, R_p^* = C_H - C_L, R_s = 0$.[63] As before, the measure of efficiency is the sum of surplus: $W \equiv CS + V_1 + V_2$, where $CS \equiv$ the present value of consumer surplus and $V_i \equiv$ present value of producer surplus, $i = 1, 2$. The social discount rate

(r) is the same for all components of this measure of efficiency; distributional issues are suppressed.

Efficiency is increased or unaffected when tying and level royalties are allowed. For drastic innovations, there is no licence and no tying. For nondrastic innovations, $V_2 = V_2^N$ and $V_1^H = \Phi_1$ under both "Tying" and "No Tying".[64] The only change in efficiency moving from one regime to the other is in consumer surplus, which is greater (or unchanged) when tying is permitted. Comparing the level royalty (R_s^*) under the hybrid licence, when tying is permitted, to the royalty on the patent (R_p^*) when it is prohibited: $CS(R_s^*) \geq CS(R_p^*)$ as long as $e^{-rT} \geq 0$. For a given discount factor, the level royalty provides the greatest increase in efficiency, moving from "No Tying" to "Tying".

If tying is permitted but level royalties are not, then moving away from the level royalty, with its low royalty rate during the patent term ($R_p = 0$, $R_s^* > 0$), there is still an increase in efficiency when changing to a more permissive regime (and so with the tying in the hybrid permitted, $R_s > 0$, but $R_p > 0$ since level royalties are prohibited) but it is not as large as when the licensor chooses level royalties.[65] There is a range of efficiency improvements corresponding to the range of royalties available to the licensor: at one end is the sole patent royalty; at the other end is the maximum efficiency gain possible with level royalties.[66]

The assumptions ruled out a negative fixed fee. Even without a hybrid or tying contract, restricting output to the monopoly level during the patent term could be achieved if the licensor pays an amount equal to the profits the licensee would have received without a licence, V_2^N, for Firm 2 to agree not to produce any output.[67] However, the two firms could not coordinate their actions using *only* the instruments presented here (non-negative fixed fees and royalties): Firm 2

can be neither coerced nor induced to cooperate. In the absence of a technology that provides Firm 1 with a sufficient cost reduction to drive Firm 2 out of the market (a drastic innovation), efficiency-reducing monopolization requires some coordinating mechanism outside the scope of this study.

III. CONCLUSIONS

Courts have expressed concern that hybrid licences allow a patent-holder to leverage any market power afforded by the patent into the post-patent period. As the licensing example with renegotiation showed, this concern is not unfounded. The leveraging of market power relies on a particular set of parameter values and the credibility of a threat of re-contracting such that the threat would lead a potential licensee to accept an unfavourable hybrid licence to avoid the competitive disadvantage of producing without a licence while his competitor received a very favourable exclusive licence. For other parameter values - less drastic innovations, essentially - or in the absence of a credible threat, hybrid licences can enhance efficiency. To write a hybrid licence when constrained by the opportunities of the licensees, the licensor must exercise less market power for the duration of the patent in order to secure royalties in the post-patent period. The countervailing benefit to society from allowing the licensor greater freedom to contract is the reduction in royalty rate, and hence prices, during the patent period that occurs as the licensor adjusts the licence in order to induce a licensee to accept the longer term. With a hybrid licence there are higher prices after the patent period but the loss from these higher prices is not so large as to outweigh the gains during the patent period.

Compare the patent licence which implies a high royalty rate followed by a rate of zero to the hybrid licence which implies a lower rate for a longer term: if the lower rate is sufficiently low then the hybrid licence will be preferable socially.

Tying a trade secret licence to a shorter patent licence extends the time over which royalties may be paid, reducing the per period payments. Hybrid licences are private contracts that can provide a more efficient diffusion mechanism than simple patent licences, given a limited patent term. Tying can increase efficiency because the licensor is able to smooth the (distortionary) royalty stream. The smoothing effect is greatest when level royalty licences are used. But these are precisely the compensation schemes that have been rejected by the courts.

Although hybrid licences have escaped *per se* illegality under anti-trust rules, American courts applying the doctrine of patent misuse to condemn this form of tying can arrive at decisions that are excessively harsh. In the absence of a credible threat of exclusive licensing, or when the licensor is herself a producer of the final good, efficiency is generally enhanced by hybrid licensing, even when the know-how tied to the patent is a "fiction" without inherent value of any kind. Further, the results above suggest that the rule from American jurisprudence that makes level royalties illegal is an excessive restriction.

How should legislators respond to the result that permitting tying of IPRs may enhance welfare? In the United States, IPRs are not covered by the basic laws on tying; however, as the leading case in this area (*Duplan*) indicates, American courts are willing to apply patent misuse provisions in cases involving patents and tying. One suggestion for misuse law comes directly from the results: the regulation must be clarified to specify which actions constitute misuse, *i.e.*, tying of IPRs must be carefully defined and the conditions of its prohibition made clear.[68] The

movement toward evaluating tying cases for regular products under a rule of reason rather than under a *per se* illegal rule, should be echoed for the tying of IPRs. Further, laws concerning level royalties in hybrid licences should be more permissive: if the tying element of a particular hybrid licence has not been found to be harmful, it is hard to see why level royalties (if used) would be prohibited.

Other issues raised by the structure of the model but not explicitly considered include, for example, the possibility of infringement or non-infringing imitation.[69] Occasionally, infringement suits are settled out-of-court by a licensing contract; alternatively, sometimes courts impose compulsory licences. The terms of court-ordered licences are often constructed from licences between the licensor and a third party. In constructing a licence, however, courts may be reluctant to recognize that a licensor has "shifted" the patent component of royalties onto the trade secret component under hybrid licensing. As a result, court-ordered royalties or damages may be based only on patent royalties since imitation (or reverse engineering) of a trade secret is not infringement. Although the owner of the rights may wish to write licences such that the royalties on the patent are relatively small compared to those on the trade secret because the patent will expire, this would limit the compensation if the patent were infringed by a firm without a licence. A licensee, on the other hand, might be obliged to continue to pay R_s once the contract is signed, even if a legitimate imitation is developed and R_p can no longer be charged.[70] This introduces an important difference between the royalty rates.

Finally, the results have implications for the tying of other intellectual property instruments. For example, if arrangements are made for royalties for repeated use of copyright material instead of the more common practice of charging a single fee, the results carry through

for the tying of patented technology to copyrighted instructions since copyrights last longer than patents. The smoothing effect would not be as pronounced as in the model since the term of a copyright licence is not potentially infinite, unlike a trade secret licence, but some reduction of the royalties during the patent term could be gained. Tying an intellectual property instrument to an item without intellectual property protection may yield the same results: a licensor could conceivably tie an intellectual property licence to a land rental contract with an indefinite length.

The central point of much licensing literature is that an arbitrarily fixed patent length is not necessarily the best policy. This paper is meant to provide some insight into the consequences of some more flexible arrangements, taking hybrid licensing as an example. The paper does not establish reasons for altering patent length, generally, concluding instead that since some licences can increase efficiency the practice of hybrid licensing should not be *per se* illegal, that allowing some of these licences for reasons of efficiency may be a better policy. However, retaining the judicial tools to assess them would be worthwhile since it is equally true that some licences may reduce efficiency. The private nature of hybrid licensing arrangements provides policy-makers with the opportunity to retain limited length patents if these are desirable for other reasons and use licensing restrictions (or the lack of restrictions) to encourage private licensors to select the licence terms that achieve the efficiency-enhancing effects discussed here.

1. See Adams and Yellen [1976]; Blackstone [1975]; Blair and Kaserman [1978]; Bowman [1957]; Burstein [1960]; Mathewson and Winter [1990], Tirole [1988], pp.146-148 and 333-336; and Whinston [1990].

2. The convention followed in this paper is to refer to lump-sum payments that do not depend on output or sales as fixed fees and payments that vary with the level of activity as royalties.

3. Macho-Stadler, Martinez-Giralt, and Perez-Castrillo [1993], p.4.

4. Jorda [1986], p.87 in Jager [1986], p.184.

5. Rostoker [1983], p.63.

6. Macho-Stadler, Martinez-Giralt, and Perez-Castrillo [1993], pp.9-10.

7. See the assumptions regarding know-how, page 7.

8. Macho-Stadler, Martinez-Giralt, and Perez-Castrillo [1993], p.12.

9. "Consider the treatment of patent exploitation under the antitrust laws. Current law is a woeful tangle of apparently arbitrary and sometimes conflicting doctrines concerning the restrictions that patent holders may impose on licensees. Some practices that are unlikely to have adverse economic impact are illegal per se, although others, potentially more harmful, are subject to a rule of reason. Careful analysis of the efficiency considerations in this area is clearly warranted." Levin [1986], p.201. However, recognition of this potential friction between intellectual property rules and anti-trust laws has led legislators to modify competition policy to adjust the efficacy of protection. For example, anti-trust laws of most countries have ensured "that IPR owners could not be found guilty of illegal monopolization...merely by exercising their exclusive rights". Anderson, Khosla, and Ronayne [1990], p.5.

10. Tandon [1982] argues that "for process innovations subject to compulsory licensing, the optimal patent has an infinite life" since "for any given cost reduction, the social problem is to minimize the deadweight loss associated with the patent" and so "the optimal policy calls for raising the patent life as much as possible, thereby allowing the royalty rate to be kept as low as possible." (Tandon [1982], p.474-479). Gilbert and Shapiro [1990] consider patent breadth in addition to length concluding first that "[if] patent breadth is increasingly costly in terms of deadweight loss, then optimal patent policy calls for infinitely-lived patents" and second that "if profits and welfare are both concave in output, then welfare is concave in the patentee's profits, so the optimal patent lifetime is infinite." (Gilbert and Shapiro [1990], *Propositions 1 and* 2, p. 108-109).

11. Provided imitation of the patented innovation is impossible or prohibitively costly. See Gallini [1992].

12. These results have a parallel in the literature on optimal taxation. For other discussions of the issue of optimal patent design see, for example, Green and Scotchmer [1989], Klemperer [1990], or Denicolò [1996].

13. Note that since patent length is unchanged in this analysis, a hybrid licensing solution does not reduce future innovative possibilities arising from the discovery of the patented technology in the hybrid licence, unlike a solution that involves an infinite patent length. See, for example, Scotchmer [1991] for a discussion of how assessment of the net social benefit of an innovation could include its contribution to further developments.

14. For an example of an important American hybrid licensing decision see the *Duplan* case in which "purchasers of machinery for false twist yarn texturing of synthetic yarns, in being required to take out patent use licences, were required also to pay for unpatented technical information tied to such machines and nonapplicable patents and unpatented technical information tied to other patents". *Duplan Corp. v. Deering Milliken, Inc.*, 444 F. Supp. 648, 649 (1977).

15. Jager [1986], p.186.

16. The unjust enrichment doctrine is the "principle that one person should not be permitted unjustly to enrich himself at the expense of another, but should be required to make restitution of or for property or benefits received, retained or appropriated, where it is just and equitable that such restitution be made, and where such action involves no violation or frustration of law or opposition to public policy, either directly or indirectly. *Tulalip Shores, Inc. v. Mortland*, 9 Wash.App. 271, 511 P.2d 1402, 1404." (Black [1990], p.1535).

17. See also O'Reilly and Pula [1984].

18. *Brulotte v. Thys Co.*, 379 U.S. 29, 32 (1964). The *Brulotte* case, further, closes the door on the possibility that a licensor could justifiably claim that a hybrid licence with level royalties is a trade secret agreement with the patent segment provided for free.

19. See Proposition 5, page 21.

20. See Proposition 3, page 15.

21. Fixed fees are not part of any equilibrium licence in this model and strategic renegotiation is not an issue when there is only a single potential licensee and no uncertainty or random events.

22. See Proposition 7, page 27.

23. This assumption is particularly restrictive and separates this analysis from earlier work on tying, in which the tied item has some value to the purchaser independent of the value of the tying item.

24. This assumption implies that these instructions are of no benefit to a user of the old technology. While it might be convenient to suppose that the trade secret could consist of instructions detailing the most efficient use of the patented technology, this supposition would violate "best use" provisions found in most countries' patent laws which oblige patent applicants to reveal the best use of their innovation before a patent is granted. A successful applicant who fails to disclose this information runs the risk of having the patent ruled invalid at a later date.

25. For an example of a long trade secret contract, see *Warner-Lambert Pharmaceutical Co. v. John Reynolds, Inc.*, 178 F.Supp. 655, 123 U.S.P.Q. 431 (S.D.N.Y. 1959), *aff'd*, 280 F.2d 197 (2nd Cir. 1960).

26. A survey concerning methods of licensing compensation found that "a down payment with running royalties was used 46% of the time, while straight royalties and paid-up licences accounted for 39% and 13% respectively. Other forms of compensation such as periodic lump sum payments, cross licensing, stock equities and royalty free licences...were used an insignificant portion of the time (2%)". Rostoker [1983], p.64. See also the discussion in the introductory section of this paper.

27. Level royalties, *i.e.*, constant royalties for all t, are not ruled out in the analysis. If tying is permitted the licensor could choose to set $R_p = 0$, and $R_s > 0$, that is, royalty rates would not decline with patent expiration in the hybrid licence.

28. The innovations considered here relate only to the production process and are not new consumer goods.

29. However, note that in a situation where the innovation was patented by a producer of the final good, in the pre-production (contract-setting) stage the licensor can act as a Stackelberg leader since equilibrium quantities depend on contract terms.

30. This assumption eliminates the complication of infringement.

31. During the patent term the licensor can receive both royalties, R_p and R_s, per unit of output multiplied by the output level chosen by the licensee. With a discount rate of r, revenues during this term, $0 \leq t \leq T$, are discounted by $\frac{1-e^{-rT}}{r}$.

After the patent expires, the licensor can receive only the trade secret royalty multiplied by the licensee's output; revenues that accrue during this period are discounted by $\frac{e^{-rT}}{r}$. A fixed fee is not discounted since this amount would be paid at $t = 0$.

32. The initial solutions presented here are from a simple subgame perfect Nash equilibrium. A more complex structure that includes the possibility that licences may be renegotiated after the initial round of contract offers by the licensor is discussed later in the paper.

33. Constraint 1 does not have the form $V_i^{HN} \geq V_i^{NH}$ due to symmetry, especially in information. The licensor is unable to induce a licensee to accept a punishing contract by threatening to licence the other firm at favourable terms because such a threat would not be credible. If $V_i^{HN} = V_i^{NN}$, for the current offer, both potential licensees know that this offer is the best that the licensor can do. If $V_i^{HN} > V_i^{NN}$, then the licensor cannot do better than to offer a license that maximizes her royalty revenue. $V_i^{HN} \geq V_i^{NH}$ would be the form of the relevant constraint if the licence were offered by auction (not considered in this paper) or if the licensor were able to secretly renegotiate licences with one or both of the licensees after the initial licence offer. This latter possibility, of renegotiation, is discussed below.

34. In this initial case, without renegotiation or other strategic adjustment of licence terms, if it is optimal to license only one firm, the licensor randomly selects one of the two identical firms. The licensor will always license the technology, $n > 0$, provided at least one of the firms will accept a contract with any positive terms since the licensor makes nothing otherwise: $V_0^{NN} = 0$.

35. Although the use of the patented innovation is verifiable, and thus abandonment of the technology under a patent-only licence would relieve a licensor of further royalty payments, the use of the trade secret is not verifiable since it is a fiction constructed for the purpose of extending licence length. A licensee may therefore be obligated by the terms of the contract to pay for the know-how in the licence indefinitely, as long as he continues to produce the good covered by the trade secret. See the assumptions, starting on page 7, for the conditions that are required for this kind of contracting. In particular, output must be observable and verifiable.

36. In an auction, or when the licensor can threaten to licence the other producing firm, a potential licensee would be willing to pay more than the fixed fee in (2) since if he doesn't gain access to the new technology, the other firm will. See the licence in Equation (8), below.

37. The primary policy concern here would be whether the prevailing patent length provides sufficient rewards to an innovator such that she would undertake the optimal level of investment in research. However, recall that this paper takes an *ex post* approach to the analysis of optimal diffusion: innovative activity has already occurred before the start of the licensing game. The issue of research incentives is resolved by assuming that the prevailing patent length was sufficient to induce the research required for the innovation.

38. Monopoly output with unit cost of C_L is $\frac{1}{2}(a - C_L)$. The patent royalty that would induce this level of output from the two Cournot duopolists is $\frac{1}{4}(a - C_L)$ such that each firm produces $\frac{1}{4}(a - C_L)$ during the patent period.

39. To arrive at the licence in (7), maximize V_0 subject to (5) and $R_p = 0$.

40. The licensees would only accept the hybrid licence in (7) if $4(1 - e^{-rT})(1 - \gamma) \geq 1$ but the licensor would only offer such a licence if $16(1 - e^{-rT})(1 - \gamma)^2 \leq 1$, that is, if the hybrid licence in (7) provided greater returns than the patent-only licence in (6). Combining these two conditions implies that the only parameter values that would (weakly) secure hybrid licensing as an equilibrium are: $e^{-rT} = 0$ and $\gamma = 3/4$. For these parameter values, the two conditions are exactly equal; the licensor and the licensees are indifferent to the choice of licence type and thus are indifferent between the tying contract and the contract without tying. Further, the present value of consumer surplus is the same for both types of licence. However, with $e^{-rT} = 0$, the issue of the length of licence is made irrelevant since surplus in the post-patent period has no value.

41. See also Kamien and Tauman [1985] who show that the private value of a patent is highest with the use of fees only, or Katz and Shapiro [1986] who derive profit-maximizing patent licensing fees under the assumption that output is not observable.

42. For most nondrastic innovations, that licence would be:

$$n = 1, F = \frac{1-e^{-rT}}{r}\left(\frac{a+C_H-2C_L}{2}\right)^2 - \frac{e^{-rT}}{r}\left(\frac{a-C_H}{2}\right)^2, R_p = 0, R_s = 0,$$

where the fixed fee is the increase in returns from operating with the lower cost of C_L while the competitor continues to face the higher cost of C_H.

43. This licence is not feasible for trivial innovations, such that $3/4 \leq \gamma < 1$, since $R_s = ½(a - C_L)$: the hybrid royalty rate would exceed the reduction in unit costs, $C_H - C_L$, for these innovations.

44. The extreme values for this condition are $\{\gamma = ½, 0 \leq e^{-rT} \leq 9/16\}$ and $\{½ < \gamma \leq 7/8, e^{-rT} = 0)$.

45. See Law [1997] for further details.

46. While it might appear that *two* policy variables are changing (the illegality of tying *and* of level royalties), the inclusion of level royalties is a minor point. Note that setting level royalties implies tying. If it is permissible to tie but illegal to set $R_p = 0$, then the licensor could set $R_p = \epsilon$ (a small royalty that is just sufficient to avoid illegality) which would have no impact on profits (to the first order). The crucial issue is the availability of a means to extend the length of the licence in the presence of a time limit on patent protection.

47. Further details of this proof can be found in the Appendix to Part 1, Law [1997].

48. See also the discussion of fixed fees following the presentation of the model in which the licensor is a producer of the final good.

49. See, *e.g.*, Rostoker [1983] or any of the other studies mentioned in the introductory section.

50. Contractor [1981], p.36.

51. Macho-Stadler, Martinez-Giralt, and Perez-Castrillo [1993], p.12.

52. Further details of the derivation are provided in Law [1997].

53. However, the licensor prefers to receive royalties from both firms.

54. Recall that returns to the patent-holder were not fixed *ex ante*, in contrast to the models of Tandon [1982] or Gilbert and Shapiro [1990], so returns to the innovator for a given innovation depend on licence terms chosen after development and determined by parameters such as the cost reduction arising from the use of the new technology, market conditions, and patent policy (T).

55. This observation does not hold for the other constrained hybrid royalty, in region 3, which is certainly lower than the comparable patent royalty for $e^{-rT} > 1/9$, which is precisely the boundary between this constrained hybrid royalty and the unconstrained royalty.

56. The potential licensee was assumed to be incapable of imitating the patented technology: recognizing the possibility of imitation would further constrain the contract terms available to the licensor, reducing the range for which hybrid licensing would be inefficient. This effect would be particularly pronounced in the worst case considered above, that is, with "impatient" agents (e^{-rT} near 0) who would not want to wait for the expiration of the patent to gain access to the technology. See also Gallini [1991].

57. The licensor's ability to choose the competition after the expiration of the patent is limited in this model. For $t > T$, there is one possible market structure: duopoly. For further discussion of the incentives that exist for a licensor to selectively license firms that could be potential competitors after patent expiration, see Rockett [1990].

58. All results discussed in this paper are from subgame perfect Nash equilibria.

59. Although it might appear, at first glance, that one could obtain F from the constraint, substitute for F in V_1, and solve to get $R_p = 0$ and $R_s = \frac{1}{2}(a - C_L)$, this solution is not feasible. This trade secret royalty would push the licensee's production to zero for all time, violating the participation constraint. Note also that in this situation, unlike for versions of the model in which the licensor does not produce the final good, licences in which both $R_p > 0$ and $R_s > 0$ could be optimal for the licensor.

60. Recall that a licensor who does not produce the final good strictly prefers patent-only royalties for nondrastic innovations (when renegotiation is not possible). The difference in this situation is that one producer, the innovator here, pays no royalties whatsoever. There is no opportunity for a potential licensee to reject a licence and produce with the old technology and no royalties while his competitor pays royalties for the new technology since the competitor owns the intellectual property right.

61. Since the licensor holds V_2^H constant, an increase in the trade secret royalty rate must necessarily be paired with a decrease in the patent royalty rate.

62. A higher discount rate for the licensee than for the licensor, $r_2 > r_1$, implies $V_1^H(R_s^*) > V_1^H(R_p^*)$.

63. Note that this licence is one extreme of the set of licences that the licensor finds acceptable when tying is permitted and $r_1 = r_2 = r$.

64. It is this result which most closely parallels the work of Gilbert and Shapiro [1990]. For given patent breadth, the licensor's returns could be fixed at Φ_1 *ex ante*, rather than observing that they are limited to Φ_1 *ex post*.

65. To see this result, given $\frac{\partial R_s}{\partial R_p} = -1 - \frac{e^{-rT}(a - C_L - 2R_s)}{(1 - e^{-rT})(a - C_L - 2R_p - 2R_s)}$ from $V_2^H - V_2^N = 0$ and

$$CS = \frac{1 - e^{-rT}}{r}\frac{1}{2}\left(\frac{2(a - C_L) - R_p - R_s}{3}\right)^2 + \frac{e^{-rT}}{r}\frac{1}{2}\left(\frac{2(a - C_L) - R_s}{3}\right)^2, \text{ then } \frac{\partial CS}{\partial R_s} \geq 0 \text{ as long as } R_p \geq 0, R_s \geq 0.$$

66. Level royalties are better than a high R_p followed by low R_s. Suppose that the know-how is costly to develop and valuable (*i.e.*, that the patent reduces unit cost from C_H to an intermediate level, C_M, and the know-how further reduces unit costs to a low level, C_L). In this situation, even when tying is prohibited the patent royalty rate could be lower than in the current situation where the trade secret is a fiction since some of the royalty burden could be shifted from the patent to the trade secret although not as completely as when tying is permitted. At the extreme, with tying prohibited and no possible imitation of the know-how, R_p could be as low as $C_H - C_M$, with a trade secret royalty, R_s, of $C_M - C_L$.

67. Firm 1 has an incentive to pursue some kind of coordinating mechanism provided the returns are greater than from licensing, which is the case for a subset of nondrastic innovations. The licensee, though, has an incentive to cheat on such an agreement by accepting the payment but producing with the old technology anyway. There is no repetition to this game that could provide a framework for the cooperation required to sustain monopolization with nondrastic innovations. Regardless of the incentives in the licence that Firm 1 provides to Firm 2 to deter production, Firm 2 is better off producing, unless payment of the fixed fee could be stretched out over the patent term to eliminate Firm 2's incentive to renege. A licence which explicitly prevents Firm 2 from producing would be, clearly, illegal. Negative fixed fees need not be specified in a licence, however, thus making detection difficult. For example, Firm 1 could agree to purchase an asset from Firm 2 at an inflated price: the difference between the price paid and the

actual value of the asset would be equivalent to the fixed fee. This practice avoids illegality: there is no law against voluntarily paying too much. There are a variety of contracts which could result in coordination. Another possible coordinating mechanism is for Firm 1 to sell Firm 2 production equipment embodying the new technology with the proviso that Firm 2 sell the old equipment to Firm 1 (to prevent cheating). The licensor would agree to sell only as much equipment as would leave the licence with just enough capacity to produce the monopoly output. With an appropriate price for the output and equipment transfers, Firm 1 could capture monopoly profits less V_2^N.

68. The results of the models suggest that one test should be to determine whether the royalty rate in a hybrid licence is significantly lower than the royalty rate that would have been set if the licence were for the patent only. The difficulty with this test is that it may be difficult to establish a royalty rate for a hypothetical patent-only licence.

69. The remedy for infringement is often a compulsory licensing arrangement although it is the imitator, in this case, who is compelled to pay a royalty for the patented technology (rather than an innovator who is required to offer a licence). If this is assumed it would have particular importance to the results of this model: the issue is whether damages are based solely on the terms of licensing contracts (if any), or are calculated on the basis of profits lost due to infringement, or also include some return on the incurred cost of developing the innovation.

70. In addition to cases cited above concerning the length of trade secret royalty obligations, see *Span-Deck, Inc. v. Fab-Con, Inc.*, 677 F.2d 1237, 215 U.S.P.Q. 835 (8th Cir. 1982), *cert. denied*, 459 U.S. 981 (1982), and *Chromalloy American Corp. v. Fischmann*, 716 F.2d 683, 221 U.S.P.Q. 311 (9th Cir. 1983). However, the contract must specify separate rates on the patent and the know-how: see *Boggild v. Kenner Products*, 576 F.Supp. 533, 222 U.S.P.Q. 393 (S.D. Ohio 1983).

TABLES AND FIGURES

Table 1. Hybrid License Terms (Renegotiation Not Possible, F = 0)

Hybrid Royalty	Conditions	Constraint 2
$R_s = \frac{1}{2}(a - C_L)$	Region 1: drastic innovations, low discount factor	not binding
$R_s = \dfrac{1 - (e^{-rT})^{0.5}}{1 + (e^{-rT})^{0.5}}(a - C_L)$	Region 2: drastic innovations, high discount factor; and very drastic innovations, intermediate discount factor	binding; rejecting the licence implies zero profits for $0 \le t \le T$ for a potential licensee if the other accepts
$R_s = \dfrac{(1 - e^{-rT})(a - C_H)(C_H - C_L)}{(1 - e^{-rT})(a - C_H) + e^{-rT}(a - C_L)}$	Region 3: some drastic innovations, intermediate discount factor; AND	binding
	Region 4: nondrastic innovations	binding

See Figure 2, for a graphical depiction of the relevant parameter boundaries for the various licences.

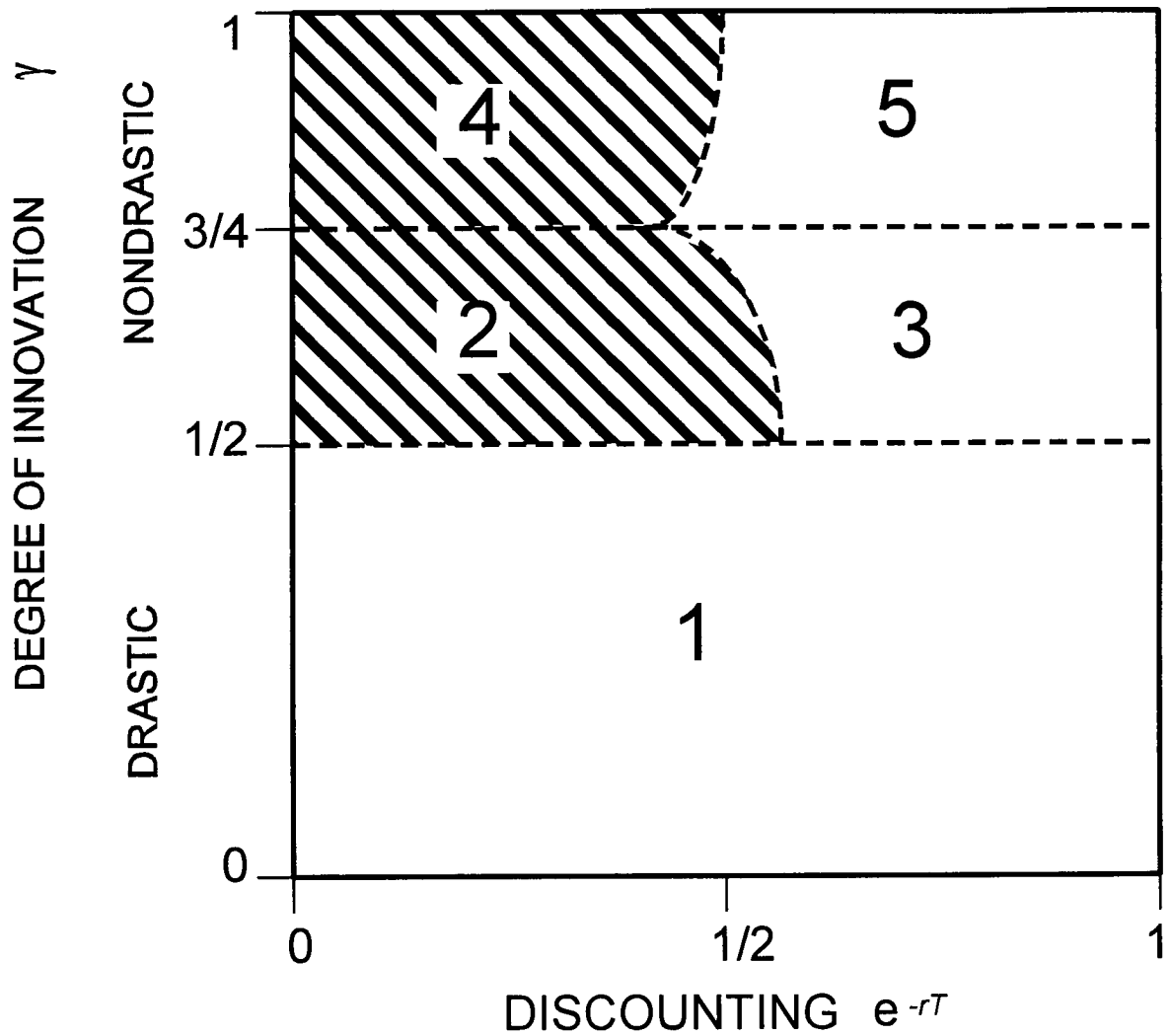

Figure 1. Licence offers from a non-producing licensor to a Cournot duopolist: Feasibility conditions and efficiency comparisons when renegotiation is possible and fixed fees are available. [Notes on following page]

Notes for Figure 1. Licence offers from a non-producing licensor to a Cournot duopolist: Feasibility conditions and efficiency comparisons when renegotiation is possible and fixed fees are available.

ROYALTIES

Table 2. Licence Structures (Renegotiation Possible)

Region	Conditions	"Tying" licence	"No-tying" licence
1	$1/2 > \gamma > 0$	------	------
2	$3/4 > \gamma \geq 1/2$ and $\gamma(1-\gamma)(1-e^{-rT}) \geq 7/64$	$F = F(R_s = \frac{1}{4}(a - C_L))$ $R_p = 0$ $R_s = \frac{1}{4}(a - C_L)$	$F = F(R_p = \frac{1}{4}(a - C_L))$ $R_p = \frac{1}{4}(a - C_L)$ $R_s = 0$
3	$3/4 > \gamma \geq 1/2$ and $\gamma(1-\gamma)(1-e^{-rT}) < 7/64$	$F = 0$ $R_p = 0$ $R_s = a - C_L - [9rV_i^{NE}]^{1/2}$	$F = F(R_p = \frac{1}{4}(a - C_L))$ $R_p = \frac{1}{4}(a - C_L)$ $R_s = 0$
4	$1 > \gamma \geq 3/4$ and $4\gamma(1-e^{-rT}) - \gamma \geq 1$	$F = F(R_s = C_H - C_L)$ $R_p = 0$ $R_s = C_H - C_L$	$F = F(R_p = C_H - C_L)$ $R_p = C_H - C_L$ $R_s = 0$
5	$1 \geq \gamma \geq 3/4$ and $4\gamma(1-e^{-rT}) - \gamma < 1$	$F = 0$ $R_p = 0$ $R_s = a - C_L - [9rV_i^{NE}]^{1/2}$	$F = F(R_p = C_H - C_L)$ $R_p = C_H - C_L$ $R_s = 0$

The fixed fees in Table 2 are given by:

$$F\left(R_p = \tfrac{1}{4}\left(a - C_L\right)\right) = \frac{1-e^{-rT}}{r}\left(\frac{a - C_L}{4}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a + C_L - 2C_H}{3}\right)^2; \tag{26}$$

$$F\left(R_p = \left(C_H - C_L\right)\right) = \frac{1-e^{-rT}}{r}\left(\frac{a - C_H}{3}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a + C_L - 2C_H}{3}\right)^2; \tag{27}$$

$$F\left(R_s = \tfrac{1}{4}\left(a - C_L\right)\right) = \frac{1}{r}\left(\frac{a - C_L}{4}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a + C_L - 2C_H}{3}\right)^2 - \frac{e^{-rT}}{r}\left(\frac{a - C_L}{3}\right)^2; \text{ and} \tag{28}$$

$$F\left(R_s = \left(C_H - C_L\right)\right) = \frac{1}{r}\left(\frac{a - C_H}{3}\right)^2 - \frac{1-e^{-rT}}{r}\left(\frac{a + C_L - 2C_H}{3}\right)^2 - \frac{e^{-rT}}{r}\left(\frac{a - C_L}{3}\right)^2. \tag{29}$$

EFFICIENCY

shaded area: welfare decreased with tying

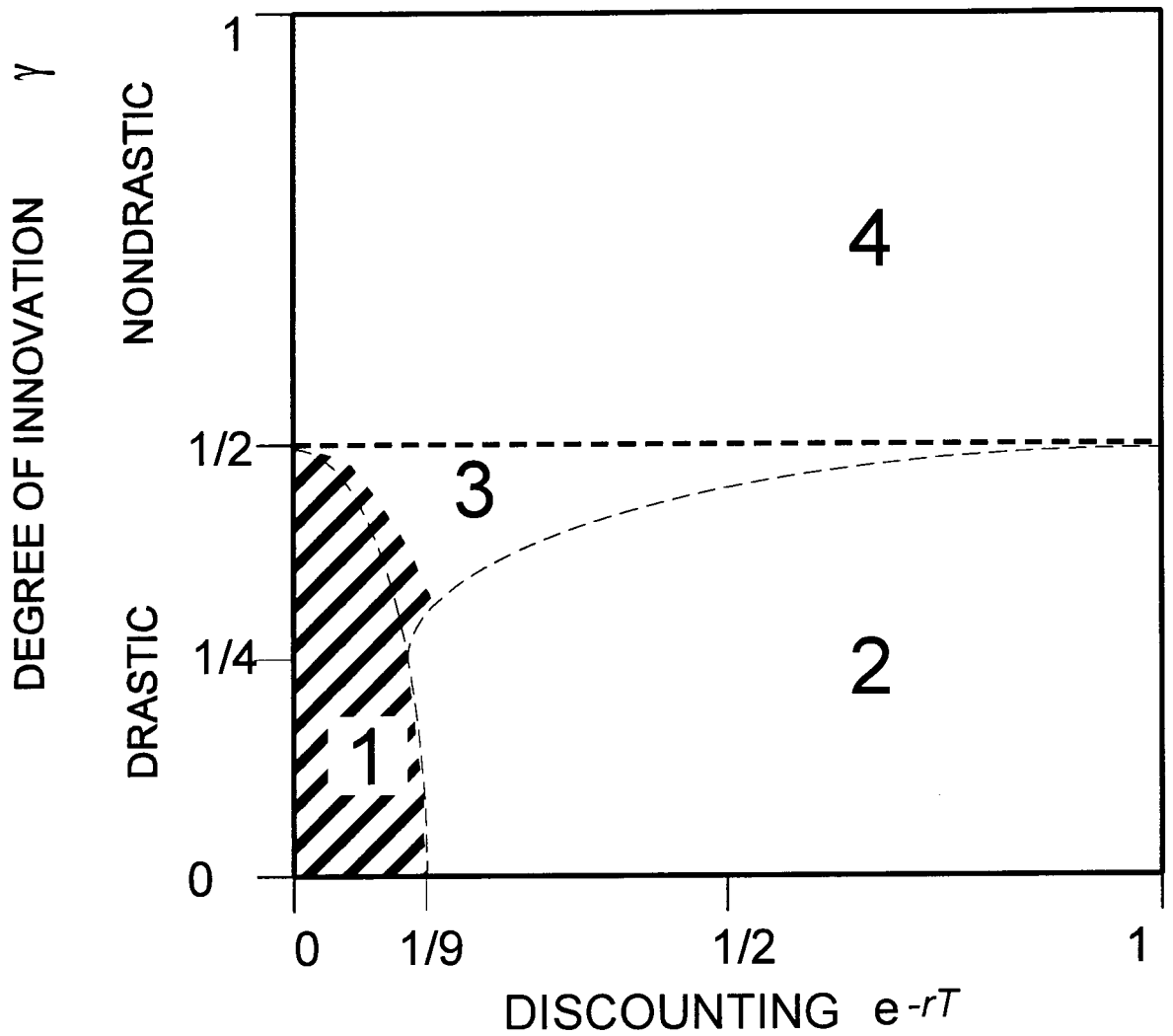

Figure 2. Licence offers from a non-producing licensor to a Cournot duopolist: Feasibility conditions and efficiency comparisons of hybrid licences when renegotiation is not possible and fixed fees are unavailable. [Notes on following page]

Notes for Figure 2. Licence offers from a non-producing licensor to a Cournot duopolist: Feasibility conditions and efficiency comparisons of hybrid licences when renegotiation is not possible and fixed fees are unavailable.

ROYALTIES

Table 3. Licence Structures (Renegotiation Not Possible, F = 0)

Region	"Tying" Hybrid licence	"No Tying" Patent-only licence	Feasibility conditions for Tying Licence
4	$R_s = \frac{(1-e^{-rT})(a-C_H)(C_H-C_L)}{(1-e^{-rT})(a-C_H)+e^{-rT}(a-C_L)}$	$R_p = C_H - C_L$	$\{½ \le \gamma < 1, 0 \le e^{-rT} \le 1\}$
3	$R_s = \frac{(1-e^{-rT})(a-C_H)(C_H-C_L)}{(1-e^{-rT})(a-C_H)+e^{-rT}(a-C_L)}$	$R_p = ½(a - C_L)$	$\{¼ \le \gamma < ½, H_2 \le e^{-rT} < 1/9\}$ and $\{H_1 \le \gamma < ½, 1/9 \le e^{-rT} \le 1\}$
2	$R_s = \frac{1-(e^{-rT})^{0.5}}{1+(e^{-rT})^{0.5}}(a - C_L)$	$R_p = ½(a - C_L)$	$\{0 < \gamma < H_1, 1/9 \le e^{-rT} \le 1\}$
1	$R_s = \frac{1}{2}(a - C_L)$	$R_p = ½(a - C_L)$	$\{0 < \gamma < ¼, 0 \le e^{-rT} < 1/9\}$ and $\{¼ \le \gamma < ½, 0 \le e^{-rT} < H_2\}$

EFFICIENCY

shaded area: welfare decreased with tying

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