Socially excessive dissemination of patent licenses

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As compared to the social optimum, a monopolist usually sells too little. This result seemingly includes the case of a lab that licenses its patented cost innovation: Katz and Shapiro (1986) find "conditions under which [the lab] will issue fewer than the socially optimal number of licenses." However, I find instead that its incentives can be socially too high; the monopoly seller may sell too much. For example, it can be profit maximizing to sell several licenses while it is socially optimal that none are sold.

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"If one wants to induce firms to undertake R&D one must accept the creation of monopolies as a necessary evil." Schumpeter (1943)

Schumpeter's "necessary evil" of patents is, of course, that a monopolist sells too little; its price is above marginal costs. Indeed, it is usually argued that ideally innovations (like other products) should instead be sold at cost. For example, Ordover (1991) notes that "static efficiency considerations mandate that the knowledge asset, resulting from R&D [...] be made widely available to those who are willing to pay the low marginal cost of dissemination." Katz and Shapiro (1986) confirm this view in a model with a lab that licenses an innovation to competing firms, finding that the lab's "incentives to disseminate the innovation typically are *too low*" and that "it is socially optimal for licenses to be issued to all..." This result has been confirmed since, most recently in Sen and Tauman (2007) who show that this result holds under general licensing schemes (see also Sen and Tauman for an overview of work examining the welfare question since Katz and Shapiro 1986).

This paper shows that when a lab is selling a non-drastic cost innovation, the lab's incentives to disseminate the innovation can be *too high* rather than too low. Further, if installing the innovation entails a fixed cost, then the monopolist's profit maximizing output can be *greater* than the social welfare maximizing output.[1] For example, it may be profit maximizing for the lab to sell many licenses when it is socially optimal that zero are sold. Hence, a monopoly may be a good rather than a necessary evil precisely because it would sell the fewest units.

These results have several implications on economic policy. First, the finding here that licensing can be socially excessive suggests that the common governmental policy of promoting

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[1] Teece (1976) suggests that such costs are on average 19% and as much as 59% of total costs, and are greater on average than the licensing fees. Caves', et al. (1983) find that "[t]he preparation and contract costs involved in transferring technology are not trivial, and they strongly qualify the public good character that economists assign to technology transfer." More recent evidence regarding the fixed costs and their effect on technology transfers is found in Astebro (2002) and Serrano (2006). In particular, Serrano (2008) shows that positive costs of technology adoption are required to make a model of technology transfer match the actual patterns of patent transfers. See also Boldrin and Levine's (2004) argument that ideas are rivalrous.

technology transfers (see, e.g., Bozeman 2000) could actually be welfare worsening.[2] In particular, governments often encourage Research Joint Ventures (*RJVs*) because "they guarantee diffusion" (Grossman and Shapiro 1996), but the results here indicate that this may be a reason to, instead, discourage *RJVs*.[3,4] Indeed, this turns one of Katz and Shapiro's (1986) concerns regarding *RJVs* – a *RJV* may issue too few licenses – on its head, as here it is shown that 'issuing too few licenses' could be a good thing.[5] This raises another policy issue: if all members do receive a license, then a larger *RJV* means more licenses, and so the findings here indicate that restricting the size of a *RJV* could be welfare improving. The results here also indicate that the common policy prescription of public dissemination (see, e.g., the discussion in Kremer 1998) could be the worst of all possible policies. Finally, Faulí-Oller and Sandonís (2003, 2007) compare the welfare effects of merging versus licensing, finding the latter usually to be welfare superior. If, however, a merger lowers transfers costs, then this could tip the balance towards instead a merger being superior.

The model used here is based on Katz and Shapiro (1986), which nests many papers and so covers a wide range of settings. First, different ownership structures are considered: in addition to considering a licensor that is independent of the downstream firms, the effects of vertical integration are considered (such as occurs in a *RJV*s). Second, different licensing (selling) strategies are considered: auctions, the optimal two-part pricing, and at cost pricing (i.e., public dissemination).

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[2] Bozeman (2000) states that "Since 1980, the US Congress has passed no less than eight major policy initiatives dealing with technology transfer and means of promoting it; similar trends have occurred in other nations." In Europe, the EU's CORDIS lists among its purposes as "promoting and locating transferable technologies" while in Canada there is the governmental Federal Partners in Technology Transfer.

[3] For example, in the United States the National Cooperative Research Act of 1984 was passed to make *RJVs* easier to form (Grossman and Shapiro 1996). In fact, Folsters (1995) notes that most Europe programs that subsidize cooperative R&D specifically require a "result-sharing" agreement, and that in the U.S. the MCC required the results to be licensed to all partner (either with zero royalty or at 'reasonable' rates).

[4] Grossman and Shapiro (1996) note that "A cooperative research effort may be viewed as an ex ante licensing agreement with zero licensing fees: the participants in the joint venture agree to make all research results available to members, usually with no additional fee above and beyond the initial cost of joining the venture."

[5] Further, antitrust restrictions on revenue transfers between *RJV* members could also be inadvertently welfare reducing. This is because it may be optimal for the *RJV* to give only a subset of members a license and the remaining firms a compensating transfer (Katz and Shaprio 1986). If antitrust restrictions disallow such revenue transfers, then the *RJV* will license to all members, which can reduce welfare.

Finally, the downstream market is not restricted to a duopoly, which in some instances can have a critical effect. In all of these environments, the profit from a license can be greater than its social value, and as a result the equilibrium number of licenses can exceed the social welfare maximizing number of licenses when there are fixed costs of installation.[6]

Given the extensive literature on licensing it may seem surprising that the question here has not already been examined. Or, more to the point, it may seem at first glance that the answer here has been previously derived. However, previous derivations regarding the efficiency of licensing, rather than making the result here obvious, make it instead, surprising. To begin with, Katz and Shapiro (1985) do derive conditions for licensing to reduce social welfare. But the same conditions imply that licensing is not profitable, i.e., licensing does not occur when it reduces welfare. Indeed they show the opposite: if licensing is profitable, then it raises welfare.[7] In contrast, I derive conditions for profitable licensing to reduce welfare, seemingly contradicting their results.[8] Second, Katz and Shapiro (1986) do show that licensing reduces producer surplus (generalized in Segal 1999). However, this makes the result here surprising since normally what reduces producer surplus *increases* welfare (e.g., going from a monopoly to perfect competition). Confirming this intuition, Katz and Shapiro (1986) and Sen and Tauman (2007) find that licensing always increases welfare. In contrast, I derive conditions under which licensing will reduce welfare.[9] A third welfare result, noted by Shapiro (1985), is that licensing could potentially reduce welfare if, as Sandonís and Faulí-Oller

[6] Fixed costs associated with the production choice also have a welfare role in other literatures such as strategic outsourcing (Shy and Stenbacka 2003) and vertical contracting (Jansen 2003). However, there the marginal costs are identical regardless of the production choice (e.g., in Shy and Stenbacka (2003) in house and outsourced production have the same marginal costs), while here a license decreases a firm's marginal costs.
[7] Katz and Shapiro (1985, p. 510): "[T]he private incentives to license fall short of the social ones…" They "[determine] the set of innovations for which fixed-fee licensing is privately attractive, and [show] that this set is strictly smaller than the set of innovations for which licensing is socially beneficial…"
[8] The differences between Katz and Shapiro (1985) and here arise from three assumptions in Katz and Shapiro (1985): a duopoly market; one of the duopolists owns the patent; and the owner uses two-part pricing. When any two of these three assumptions is relaxed (i.e., two of the following hold: there are three or more firms in the market, the patent holder is independent of the firms; or an auction is used instead of two-part pricing), then, as shown here, their result does not hold.
[9] This difference partly arises because with no fixed costs marginal welfare is always positive.

(2002) put it, "the royalty works as a collusive device." However, here the royalty rate is zero (as this maximizes profits when two part pricing is used when there is no collusive motive, Kamien and Tauman 1986) and there is no collusive effect here to drive the welfare loss.

There are two reasons for the results here. First, a firm's private value of the cost innovation is greater than the social value, even for the first license. This is because part of its private value comes from capturing other firms' profits, which has no social value – what is often referred to as the "business stealing effect" (Mankiw and Whinston 1986). Second, the lab's profit maximizing licensing strategy is an auction, which increases the firm's willingness to pay without changing the ex-post outcome. Essentially, if the firm does not win the license another firm does. This increases the lab's private gain from auctioning a license without adding any social benefit.

Though the role that the business-stealing effect has in making entry socially excessive has been extensively studied (e.g., von Weizsäcker 1980, Mankiw and Whinston 1986, Suzumura and Kiyono 1987, and Okuno-Fujiwara and Suzumura 1993), its role in licensing (and causing a monopolist to sell too much rather than too little) has not been considered. In addition, there are aspects from the environment here that make socially excessive licensing surprising. One is that a monopoly controls the number of low cost firms while in entry models there is free entry. As a result, without the business-stealing effect licensing would be socially insufficient, while entry would be socially efficient. The implication is that for licensing to be socially excessive, the business stealing effect must not only exist, but be greater than the inefficiency created by the monopoly (Schumpeter's necessary evil). In contrast, for there to be excessive entry only requires that the business stealing effect exists. The second is that with vertical integration (*RJV*s), downstream firms control the number of licenses. As a result, the *RJV* sells fewer licenses than the independent lab. Despite this, there still can be excessive licensing even when downstream firms control the licensing.

In addition to these differences that would normally lead to socially insufficient licensing, there are new effects here that minimize the business stealing effect, i.e., these effects do not exist in entry models. First, a license here steals business away from less efficient rivals (while an entrant steals business from equally efficient rivals). This is an efficiency gain from licensing that does not exist with entry. Second, when two-part pricing is used, the licensor realizes that its action lowers the market price and therefore reduces its profits, making the license less attractive. However, part of the business stealing effect with entry is that the entrant does *not* harm itself by entering; if it does not enter it earns zero profits. Hence, this part of the business stealing effect does not exist when two-part pricing is used. Finally, when the patent is controlled by an *RJV*, the business stealing by a new licensee is being stolen from members of the *RJV*. Hence, the *RJV* partly internalizes the business-stealing effect and excessive licensing is even less likely.

Despite all of these new effects that push licensing to be socially insufficient, there is a stronger inefficiency result here as compared to the entry models: *society may want no firms to be licensed even if it profitable for more than one firm to be licensed.* In contrast, in entry models society will want at least one firm to enter if it is profitable for one to enter, and can want one firm to enter even if it is not profitable to enter.

In the next section the benchmark model is considered: a lab that is independent of the downstream firms (the standard assumption in the literature) and uses the profit maximizing licensing strategy (auctions, Katz and Shapiro 1986). In section three, the effects of downstream ownership and public dissemination are considered and section four considers the effect of the use of two-part pricing instead of auctions. Section 5 concludes.

2. The Benchmark Model: independent lab that auctions licenses

The structure follows Katz and Shapiro (1986), Kamien and Tauman (1986), Sen and Tauman (2007) etc. Demand is $P = 1 - Q$. There are $n \geq 2$ firms that compete in quantities. Each firm has constant marginal cost C_H. A patented innovation that lowers marginal costs from C_H to C_L appears. There is an independent "lab" that holds the patent and a fixed cost f for each firm that installs the innovation. The cost reduction is non-drastic; all firms remain active if some are licensed.[10]

There are two stages. In the first stage, the lab auctions m licenses of the innovations, $0 < m \leq n$, which is the profit maximizing sales strategy (Katz and Shapiro 1986). In the second stage the firms simultaneously and independently choose output. Firm j sets output q_j with aggregate output $Q = \sum_{j=1}^{n} q_j$. Denote a low (high) cost firm's output as q^L (q^H). A low cost firm j chooses output to maximize profits,

$$\pi_j^L = [1 - q_j^L - (m - 1)q^L - (n-m)q^H - C_L]\cdot q_j^L$$

A high cost firm maximizes

$$\pi_k^H = [1 - q_k^H - (m)q^L - (n - m - 1)q^H - C_H]\cdot q_k^H$$

Using the first order conditions, and imposing symmetry yields the equilibrium outputs:

$$q^L(m) = [1 + (n - m)C_H - (n - m + 1)C_L]/(n + 1), \qquad (1)$$

$$q^H(m) = [1 - (m + 1)C_H + mC_L]/(n + 1).$$

To meet the definition of a non-drastic innovation ($q^H(m) > 0$ in equilibrium), it is assumed that

$$\bar{C}_H \equiv (1 + (n - 1)C_L)/n > C_H .$$

From (1), profits for a low (high) cost firm given m low cost firms are

$$\pi^L(m) = [1 + (n - m)C_H - (n - m + 1)C_L]^2/(n + 1)^2 = q^L(m)^2 \qquad (2)$$

$$\pi^H(m) = [1 - (m + 1)C_H + mC_L]^2/(n + 1)^2 = q^H(m)^2.$$

Welfare (since payments to the lab are a transfer) is the firms' profits and consumer surplus ($.5Q^2$) less the costs of installing the innovation:

$$W(m) = m\pi^L(m) + (n - m)\,\pi^H(m) + [mq^L(m) + (n - m)q^H(m)]^2/2 - m\cdot f. \qquad (3)$$

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[10]The model in Katz and Shapiro (1986) is more general, but the assumptions of a process innovation and homogenous good are used when deriving the welfare results (whose conditions are met by the model here).

To show that socially too many licenses are issued it is not sufficient to show that the derivative of welfare less lab profit with respect to *m* is negative because of the integer constraint.[11] Instead, differences must be used. Denote the social welfare from an additional license $\Delta W(m) \equiv W(m) - W(m-1)$. Clearly, if $\Delta W(m) > 0$, then society benefits from the m^{th} firm installing the cost reduction. In fact, if the fixed cost of installation is zero (f=0), then it is straightforward to show that $\Delta W(m) > 0$, though $\partial(\Delta W(m))/\partial m < 0$, implying that as *f* increases the welfare-maximizing *m* (denoted m^w) decreases. Finally, m^w is the greatest integer less than or equal to the *m* such that $\Delta W(m) = 0$, which equals

$$\frac{(C_H - C_L)(2n^2 + 4n + 1) + 2(n+2)(1 - C_L)}{2(C_H - C_L)(2n+3)} - \frac{f(n+1)^2}{(C_H - C_L)^2(2n+3)}.$$

Katz and Shapiro (1986) show that the lab's optimal strategy is to auction the licenses if less than *n* licenses are to be sold, and to set a price (i.e., two-part tariff with a positive fixed fee and royalty equal to zero) if all *n* licenses are to be sold. The reason an auction is optimal is as follows. If the lab sets a price, then the firm's value from buying the m^{th} license is $v(m) \equiv \pi^L(m) - \pi^H(m-1) - f$, since by buying the firm increases the number of licenses sold. With, instead, an auction of $m < n$ licenses, there will be *m* licenses sold independent of whether the firm wins the auction. That is, if a firm does not win a license, another firm will; it will be a high cost firm with *m* low cost firms. Hence, the firm is willing to bid up to $\pi^L(m) - \pi^H(m) - f$. Since including the case when *n* licenses are issued adds length to the analysis (because of the change in pricing strategy), but does not qualitatively change the analysis (see section 4 which considers the price strategy), it is omitted; it is assumed in this section that $m < n$.

The lab's revenue from auctioning *m* ($m < n$) units, then, is

$$\Pi(m,n) = m\cdot[\pi^L(m) - \pi^H(m) - f].$$

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[11] Because the number of licensees is an integer, the *m* such that the derivative equals zero is not enough to determine m^w. E.g., if the derivative is zero at m=1.5, this does not tell us whether 1 or 2 is the welfare maximizing number of licenses, while with differences if m=1.5 then 1 is the optimal number. Sen (2005) shows that ignoring the integer constraint has given misleading results in the licensing literature. See also Mankiw and Whinston (1986).

The lab's profit from auctioning an additional license when $m < n$ is

$$\Delta\prod(m,n) \equiv \Pi(m,n) - \Pi(m\text{-}1,n) = \frac{(C_H - C_L)}{(n+1)}\left[(C_H - C_L)(n - 4m + 1) + 2(1 - C_L)\right] - f\,.$$

Let m^{Π} denote the integer that maximizes profits, i.e., $\Delta\prod(m^{\Pi},n) \geq 0$ and $\Delta\prod(m^{\Pi}+1,n) < 0$. That is, it is the largest integer less than or equal to the m such that $\Delta\prod(m,n) = 0$, which equals

$$\frac{(C_H - C_L)(n+1) + 2(1 - C_L)}{4(C_H - C_L)} - \frac{f(n+1)}{4(C_H - C_L)^2}\,.$$

It is straightforward to show that $\Delta\prod(1,n) > 0$ if $f = 0$ and $\Delta\prod(m,n)$ is decreasing in m and f. Hence, there is always f such that $m^{\Pi} = 1$ and if $\Delta\prod(m',n) > 0$ for $m' > 1$, there is f such that $m' = m^{\Pi}$ (see lemma 1 and 2 below).

While a direct analysis of m^{Π} and m^{w} is possible, an indirect one is more useful. In particular note that for both the lab and society, the cost of a license (f) is identical. What differs is the benefit and simple conditions can be obtained when these diverge. Further, since earlier work assumed $f = 0$, this allows for a more clear-cut comparison to those results. Thus, first, conditions for the social value of a license m to be less than the lab's profit are obtained (proposition 1 below). Though this does not immediately establish that such an m could be the profit maximizing number of licenses (m^{Π}), as noted above there are conditions when the fixed cost of installation are such that this m is m^{Π} (lemma 1 and 2). This is because by increasing f from 0, the profit maximizing number of licenses decreases, but whether the social value of that license is greater than the lab's profit *does not change*. Thus, when the conditions for proposition 1 and the lemmas are met, there is socially excessive licensing.

Before deriving these results, some intuition as to how socially excessive licensing can be obtained by considering figure 1. If no licenses are sold, then firms are identical with marginal cost C_H with output q_0, aggregate output Q_0 and price P_0. A firm m's output is $Q_0 - (n - 1)q_0 = q_0$. If this firm m obtains a license its marginal cost decreases to C_L, aggregate output expands to Q_1 and the other firms' output decreases to $q_1 < q_0$. Firm m's output expands to $Q_1 - (n - 1)q_1$. Its gain is the diagonally striped reversed-L shaped area (which is a social benefit: lower costs and greater output) and the vertically striped rectangle (which has no social benefit). The social benefit also includes the dark triangle. Hence, if the vertically striped rectangle is greater than the sum of the horizontally striped rectangle (the firm's loss) and the triangle, then the firm's gain is greater than the social gain. Next, an auction increases the firm's willingness to pay without changing the ex-post outcome. Essentially, if the m^{th} firm does not obtain the license another firm does. Hence, the horizontally striped rectangle is no longer a loss and the vertically striped rectangle widens (as the firm now has a smaller output if it does not obtain the license): the firm's gain increases while the social benefit is unchanged. The conditions for this are in proposition 1. Next, since both the firm and society incurs the fixed costs of installation *f*, this reduces the gain to both, but does not change the fact that the firm's gain from the license exceeds the social benefit. It is clear, then, that there are *f* such that the firm's gain is greater than *f* (so the license is sold), but *f* is greater than the social benefit; this license reduces social welfare ($m^{w} = 0$) as do any further licenses sold.[12] Finally, as the lab's profit is decreasing in *m*, there is an *f* such that this is also the profit maximizing *m* ($m^{\Pi} = 1$). This point is made explicit in lemma 1 and 2.

To formally show these results, consider first the social value of a license less the lab's profit

$$\Delta W(m) - \Delta\Pi(m,n) \equiv \Gamma\cdot(C_H - C_L)/2(n+1)^2,$$

where $\Gamma \equiv (C_H - C_L)(2m - 1 + 4mn) - 2n(1 - C_L)$. Since the term $(C_H - C_L)/2(n+1)^2$ is positive, the sign of $\Delta W(m) - \Delta\Pi(m,n)$ depends on the sign of Γ, which clearly can be negative (e.g., as C_H approaches C_L). That is, the lab's profit from issuing a license can exceed the license's social value. Note, as indicated above, that that the difference ($\Delta W(m) - \Delta\Pi(m,n)$) does not depend on the fixed cost of installation as the auction price is reduced by the installation cost *f*. Conditions for the lab's value of a license to exceed its social value (i.e., for Γ to be negative) are given in (recalling that $\bar{C}_H$ is the upper

[12] If $f = 0$, then auctioning this license is profitable. As *f* increases, then since the firm's gain is greater than the social benefit, there is a sufficiently large *f* such that the lab auctions the license, but welfare decreases.

bound on high costs for an interior solution for non-drastic innovations):

Proposition 1: With an independent lab that holds the patent on a non-drastic cost innovation,

A. if $C_H \leq \bar{C}_H/2$, then $\Delta W(m) < \Delta\prod(m,n)$ for all $m < n$: with a sufficiently small cost innovation, the social value of a license is less than the lab's profit from the license.

B. if $0 < m \leq (2n^2 + 1)/2(2n + 1)$, then $\Delta W(m) < \Delta\prod(m,n)$: with sufficiently few licenses sold, the social value of the *m*th license is less than the lab's profit from the license.

C. if $n \geq 3$, then $\Delta W(1) < \Delta\prod(1,n)$: if there are three or more firms in the downstream market, the social value of the first license is less than the lab's profit.

As the proofs add no insights, the proof here and all of the following proofs are left to the appendix.

Proposition 1 gives conditions for the profit from a given license to exceed the social benefit. To complete the analysis, conditions are needed for when the (at least) *m* licenses are auctioned by the lab in equilibrium and the m^{th} license to be welfare reducing. That is, too many licenses are sold by the monopolist. From figure 1 it is clear that there are fixed costs such that this is true. To begin, the strongest statement can be made when the conditions in proposition 1.A hold as

Lemma 1: If $\Delta\prod(m,n) > \Delta W(m)$ for all $m < n$. then

A. there exist fixed costs *f* such that the profit maximizing number of licenses ($m^{\prod}$) is strictly greater than the welfare maximizing number of licenses.

B. there is no *f* such that the profit maximizing number of licenses is strictly less than the welfare maximizing number of licenses.

By lemma 1, Proposition 1.A is a condition under which the lab never sells fewer than the socially optimal number of licenses, and it could sell more than the socially optimal number.

Since parts B and C of proposition 1 do not hold for all *m* only the first part of lemma 1 can apply, which is stated as

<u>Lemma 2:</u> If $\Delta\prod(m,n) > \Delta W(m)$ for all $m < m'$, $m' \geq 1$, then there are fixed costs f such that the profit maximizing number of licenses (m^{Π}) is strictly greater than the welfare maximizing number of licenses.

Thus, by lemma 2, when either proposition 1.B or 1.C holds, then there exists installation costs such that there is excessive licensing. While the second part of lemma 1 does not apply to proposition 1.B and 1.C, proposition 1.B and 1.C do suggest that insufficient licensing is unlikely. For example, 1.C implies that for $n \geq 3$, there does <u>not</u> exist a condition (e.g., on C_H) such that $\Delta\prod(m,n) < \Delta W(m)$ for all m since we know that $\Delta W(1) < \Delta\prod(1,n)$. And, in particular, there can be excessive dissemination even if only one license is auctioned. To summarize proposition 1 and these lemmas:

<u>Corollary</u>: With an independent lab that holds the patent on a non-drastic cost innovation,

A. if $C_H \leq \bar{C}_H/2$, then i. there exist fixed costs f such that the profit maximizing number of licenses (m^{Π}) is strictly greater than the welfare maximizing number of licenses.

. ii. there is no f such that profit maximizing number of licenses is strictly less than the welfare maximizing number of licenses.

B. if $0 < m \leq (2n^2 + 1)/2(2n + 1)$, then there are fixed cost f such that the profit maximizing number of licenses (m^{Π}) is strictly greater than the welfare maximizing number of licenses.

C. if $n \geq 3$, then there are fixed cost f such that it is profit maximizing to auction only one license but it is welfare maximizing that no licenses are auctioned.

Finally, to give some sense as to how excessive licensing can be, consider the following two examples. First, let there be ten firms in the downstream market ($n = 10$) with marginal costs 2/20 (C_H = 2/20) and the innovation reduces marginal costs in half (C_L = 1/20), but installation costs are 1/140 (f =1/140). From the solutions above, $m^{\Pi} = 4$ but the social optimum is zero – even though marginal costs are halved. As a second example, let n = 15, C_H = 1.5/20 and f =1/420, then m^{Π} = 7, but the social optimum is still zero. Note that these examples also emphasize that proposition 1 gives sufficient, and not necessary conditions, i.e., even if the conditions do not hold, the lab's profit from a license can still exceed its social value, since in both examples $C_H > \bar{C}_H/2$.

3. The effect of vertical integration (research joint ventures)

Labs are often not independent of downstream firms, but rather a division of downstream firms created to make innovations, e.g., *RJV*. In other markets, the lab may be bought by, or merged with, downstream firms. Conventional wisdom is that a social cost of *RJVs* or such mergers is that they stymie the dissemination of the innovation. However, Proposition 1 suggests that this reduced dissemination could be beneficial. Likewise, forcing *RJV*s to disseminate their innovations to non-members – a potential policy to remedy the supposed cost of *RJVs* – could be instead welfare reducing.

Following Katz and Shapiro (1986), let $x \in \{0,1\ldots n\}$ be the number of firms that own the lab. Of the m firms that obtain the innovation, let $y \leq x$ be the number that belong to the *RJV*. If more than one firm owns the lab, then following the literature, it is assumed that the *RJV* sells licenses to maximize the sum of the lab and owners' profits. However, this assumption implies that revenue transfers must occur between firms when it is profit maximizing for less than all owners to have the innovation (m < x). As discussed by Katz and Shapiro (1986), this implication may be viewed as being inconsistent with the Cournot assumption that the firms set output independently, as well as being unlikely to occur in practice as anti-trust authorities would not allow transfers between firms. To remedy this, an alternative assumption will also be considered below: all firms in the *RJV* must receive the innovation.

The second stage competition between the firms is as before. Thus, the equilibrium outputs ($q^{(\bullet)}(m)$), profits ($\pi^{(\bullet)}(m)$), welfare (W(m)) and upper-limit on C_H are as before. The sum of the lab's (*RJVs*) revenue and the owner-firms' profits is, when $m < n$ licenses are sold,

$$\Pi(m,n,x,y) = y\cdot\pi^L(m) + (x-y)\pi^H(m) - y\cdot f + (m-y)\,[\pi^L(m) - \pi^H(m) - f].$$

Collecting terms, the lab chooses m to maximize

$$\Pi(m,n,x) = m\cdot[\pi^L(m) - \pi^H(m) - f] + x\cdot\pi^H(m).$$ [13]

The additional profit from a license when $m < n$ is now denoted $\Delta\Pi(m,n,x) \equiv \Pi(m,n,x) - \Pi(m\text{-}1,n,x)$ and m^{Π} is still the integer number of licenses that maximizes profits. Solving $\Delta\Pi(m) = 0$ obtains

$$\frac{[(C_H - C_L)(n+1) + 2(1-C_L)](1+n) - x(C_H - C_L + 2)}{2(C_H - C_L)(2n - x + 2)} - \frac{f\,(n+1)^2}{2(C_H - C_L)^2(2n - x + 2)}.$$

As noted in Katz and Shapiro (1986), $\partial\Pi(m,n,x)/\partial x < 0$: more firms in the *RJV* reduces the profitability of the m^{th} license. Hence, having more firms in the *RJV* diminishes the excessive licensing effect. However, one of the central results of the previous section can still hold: it can be profitable to issue more than one license while socially no licenses should be issued.

Proposition 2: If $\{x = 1$ and $n \geq 4\}$ or $\{x = 2$ and $n \geq 5\}$, then $\Delta W(1) < \Delta\Pi(1,n)$: If a downstream firm owns the lab and there are at least four downstream firms, or if two firms own the lab and there are at least five firms, then the social value of the first license is less than the lab's profit.

By proposition 2 and lemma 2, then, there exist installation costs such that the lab issues at least one license, while society would prefer that no licenses be issued.

It is interesting to compare the case of proposition 2 in which the lab owner is a firm that also competes in the downstream market to the case when the lab owner does not compete in the downstream market (proposition 1). Because a downstream firm's operational profits decrease as more rivals are licensed, a lab owner who also competes in the downstream market would license fewer firms than a lab owner that does not compete downstream. As a result, the excessive dissemination result is

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[13] An implication of $\Pi(m,n,x)$ is that an *RJV* is indifferent between a license being auctioned to outsiders or given to a member if transfers are possible.

weakened, but surprisingly only slightly: e.g., for the social value of the first license to be less than the lab's profit requires at least three downstream firms when the lab is independent and at least four firms when the lab is owned by a downstream firm. Not surprisingly, the second part of proposition 2 indicates that as more downstream firms own the lab, the excessive dissemination result requires even more downstream competitors.

If a sufficiently large number of downstream firms own the lab, then there is finally a sufficient condition for the social value to exceed the private value, the result of previous literature. Interestingly, the condition is that a majority of the downstream firms own the lab.[14] To summarize

Proposition 3: With a lab that is owned by downstream firms (*RJV*),

A. $\partial[\Delta W(m) - \Delta\prod(m,n,x)]/\partial x > 0$: as more firms own the lab the social value of the m^{th} license increases relative to its private value.

B. if $x \geq n/2$, then $\Delta\prod(m,n,x) < \Delta W(m)$: if more than half of the firms belong to the RJV, then the social value for a license exceeds the *RJVs* profit from the license.

Despite the results of proposition 3, it does not necessarily follow that as more downstream firms own the lab, socially excessive licensing is less likely. This is because, as Katz and Shapiro (1986) noted, anti-trust authorities are likely to constrain the *RJV* to disseminate the innovation to all members.[15] Katz and Shapiro (1986) further argue that one intuitively expects that membership in a *RJV* would guarantee the firm the use of the *RJV*'s output. However, this constraint was not considered in deriving proposition 3. In fact, this constraint implies the opposite: as more firms join a RJV the minimum number of licenses must increase and so excessive licensing may increase with RJV

[14] This is also part of the explanation for the apparent conflict between the results here and in Katz and Shapiro (1985) who found licensing is never socially excessive. They assume a duopoly downstream and that one of the duopolist owns the lab. By proposition 3, this is sufficient for licensing never to be excessive.

[15] If an RJV does not issue a license to all members, then there must be compensating revenue transfers to those who do not receive a license. If such transfers are illegal, then the RJV would license all members.

membership, instead of decrease as stated by proposition 3.

If the *RJV* chooses the profit maximizing number of licenses (m^{Π}) subject to the constraint that all members receive a license ($m \geq x$), then two issues arise. One is that a corner solution may arise: the profit maximizing number of licenses is strictly less than the number of members ($m^{\Pi} < x$) and so the number of members determines the number of licenses. The second is that giving a member the innovation technology does not mean the firm will install the innovation. After all, installation is costly (f). Thus, a new expression must first be derived: the social value of a license less a downstream firm's value (the previously defined v(m)): $\Delta W(m) - v(m)$.

Proposition 4: A. If $n \geq 4$, then $v(1) > \Delta W(1)$: A downstream firm's profit from having the only license is greater than its social value when there are four or more firms.

B. If $n \geq 2$ and $m \geq 2$, then $v(m) > \Delta W(m)$: A downstream firm's profit from other than the first license is greater than the social value, independent of the number of firms.

C. $\partial[\Delta W(m) - v(m)]/\partial m < 0$: as more licenses are issued, the social value of the license decreases relative to the downstream profit.

Comparing proposition 4 to propositions 1 and 2, shows that if downstream firms only pay the installation costs, then the possibility of excessive licensing usually increases. Hence, as more firms belong to the *RJV*, rather than having excessive licensing less likely (proposition 3), there is

Corollary 2: If all members of the RJV must receive a license ($m = \max\{x, m^{\Pi}\}$) and $m^{\Pi} < x$, then as more firms join the RJV, excessive dissemination is more likely.

Proposition 4 (together with lemma 2) also has an immediate implication regarding a commonly suggested policy: public dissemination (i.e., setting the price of the license to zero).

Corollary 3: If the innovation is publicly disseminated and either $\{n \geq 4, m = 1\}$ or $\{n \geq 2, m \geq 2\}$, then the private value of a license exceeds its social value and there exists a fixed cost f such that the equilibrium number of licenses is strictly greater than the welfare maximizing number.

Thus, when an independent lab is guilty of socially excessive licensing, that outcome is still welfare superior to public dissemination.

There are some interesting comparisons between the environments considered. First, with public dissemination as there are more licenses, a downstream firm's profit from a license is more likely to exceed its social value. In contrast, with an independent lab as there are more licenses, its profit is less likely to exceed the social value. Second, an independent lab's profit from the first license is likely to exceed its social value, yet under the same conditions but with public dissemination, the downstream firm's profit from having the only license can be less than its social value. This reflects the extent to which the auction strategy plays a role in the excessive licensing result.

4. The effect of two-part pricing instead of auctions

Kamien and Tauman (1986) show that with an independent lab, the profit-maximizing two-part pricing (also known as the price strategy) has a royalty equal to zero. Though this strategy does not extract as much revenue from the downstream firms as does an auction, it otherwise has no effect on welfare. Hence, the price strategy should be less likely to lead to excessive dissemination.

Since only an independent lab was examined in Kamien and Tauman (1986), it is the benchmark here. With an independent lab, the profit from selling m licenses is

$$\prod^{P}(m,n,0) = m\cdot[\pi^{L}(m) - \pi^{H}(m\text{-}1) - f] \quad \text{if } m > 0, \tag{4}$$

where the superscript P indicates price strategy. Consistent with previous notation, let $\Delta\prod^{P}(m,n,0)$ denote the additional profit of one more license. Solving for the m such that $\Delta\prod^{P}(m,n,0) = 0$ obtains

$$\frac{(C_H - C_L)(n+2) + 2(1-C_L)}{4(C_H - C_L)} - \frac{f(n+1)^2}{4n(C_H - C_L)^2}.$$

Since the welfare gain is unchanged, the social value of a license less the lab's profit now is

$$\Delta W(m) - \Delta\Pi^P(m,n,0) = \Gamma^P \cdot (C_H - C_L)/2(n+1)^2,$$

$\Gamma^P \equiv (C_H - C_L)(1 - 6m + 4mn) - (2n - 4)(1 - C_L)$. Γ^P has much the same properties as Γ. For example, as with auctions: $\partial\Gamma^P/\partial C_H > 0$ and $\partial\Gamma^P/\partial m > 0$.[16] On the other hand, it is clear from Γ^P that there need to be more than two firms in the market for insufficient licensing, while with an auction there can be insufficient licensing with only two firms in the market.

<u>Proposition 5</u>: With an independent lab that uses the price strategy and $n > 2$

A. if $C_H \leq 6\overline{C}_H/13$, then $\Delta W(m) < \Delta\Pi^P(m,n)$ for $m < n$: with a sufficiently small cost innovation, the social value of a license is less than the lab's profit from the license.

B. if $0 < m \leq (2n^2 - 4n - 1)/2(2n - 3)$, then $\Delta W(m) < \Delta\Pi^P(m,n)$: with sufficiently few licenses sold, the social value of the m^{th} license is less than the lab's profit from the license.

C. if $n \geq 4$, then $\Delta W(1) < \Delta\Pi^P(1,n)$: if there are four or more firms in the downstream market, the social value of the first license is less than the lab's profit.

A comparison of Proposition 5 to Proposition 1 shows that the basic result is unchanged, but excessive dissemination is slightly more likely with an auction than with two part pricing. For one thing, as noted above, there needs to be at least three firms in the market for excessive licensing, while with auctions there can be excessive licensing with only two firms. As another example, the critical m with the auction ($(2n^2 + 1)/2(2n + 1)$) is strictly greater than that with the price strategy ($(2n^2 - 4n - 1)/2(2n - 3)$). Thus, if the social value of the m^{th} license is less than that lab's profit with

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[16] Here is another part of the explanation for the apparent conflict between the results here and in Katz and Shapiro (1985) as they assume the firm uses a fixed fee (which they (1986) show is dominated by an auction).

the price strategy, it is also so with the auction strategy. Finally, the upper bound on the innovation is lower with the price strategy (Proposition 5.A) than with auctions (Proposition 1.A).

When the lab is owned by downstream firms the profit expression $\Pi^P(m,n,x)$ is similar to the auction case – $\Pi(m,n,x)$ – except that now the *RJV* strictly prefers to give its licenses to members. In particular, if $m \leq x$ (fewer licenses than members) then the RJVs additional revenue is identical to the additional revenue of a RJV that auctions its licenses and so nothing changes. On the other hand, if $x < m$, then the expression for $\Pi^P(m,n,x)$ is a general form of (4):

$$\Pi^P(m,n,x) = m\cdot[\pi^L(m) - \pi^H(m-1) - f] + x\cdot\pi^H(m-1).$$

Not surprisingly, the previous result that, with an independent lab, excessive dissemination is slightly more likely with auctions than with the price strategy can also be extended to the case where downstream firms own the lab. It can also be shown that the effect that an increase in downstream ownership has on the outcomes with the price strategy is essentially the same as when auctions are used (propositions 2 and 3). As these results are qualitatively consistent with the previous propositions, their derivation is omitted.

5. Conclusion

I consider the welfare effects of the dissemination (licensing) of a non-drastic cost innovation. I find, contrary to previous results, that if the innovation was made public, then a firm's profit from adopting the innovation is almost always greater than the social value. If, instead of public dissemination, the innovating lab is given a patent, then the lab's profit from selling a license still can be greater than the social value. These results are shown to hold in a range of environments. First, different licensing (selling) strategies by the lab are considered: auctions and the optimal two-part pricing. Second, different ownership structures are considered: a patent owned by some of the competing firms (*RJV*), or one that is owned by a lab that is independent of the competing firms. In all of these cases the value of selling or adopting a license can exceed its social value.

One implication of the private value exceeding the social value is that the number of licenses issued can exceed the socially optimal number in all of the environments studied here. Even a monopoly lab may disseminate the innovation more than is socially optimal. In particular, when it is profit maximizing for the lab to license several units of the innovation, it can be socially optimal that no units should be licensed. However, in such a case having monopoly power in dissemination would be welfare superior to public dissemination. Thus, patents, instead of being "a necessary evil" needed to obtain the gain of increase R&D, could be a welfare gain over public dissemination

Not surprisingly, the market environment can effect whether excess licensing occurs. For example, as more downstream firms belong to the RJV (i.e., more downstream firms are part owners of the lab), fewer licenses are issued under certain conditions. As a result, it is possible that if an independent lab issues too many licenses, an RJV with a few members may be socially preferred because it reduces the number of licenses issued. Thus, the traditional concern that vertical integration (RJVs) could lead to reduced dissemination and hence lowers welfare, may not always be justified. On the other hand, if, as Katz and Shapiro (1986) argue, the government would force the RJV to disseminate the innovation to all members, then the outcome is more likely to be again one of excessive dissemination and possibly of lower welfare. In such a case the government may prefer to have a policy restricting the size of *RJVs*.

Appendix

Proposition 1: With an independent lab that holds the patent on a non-drastic cost innovation,

A. if $C_H \leq \bar{C}_H/2$, then $\Delta W(m) < \Delta\prod(m,n)$ for all $m < n$: with a sufficiently small cost innovation, the social value of a license is less than the lab's profit from the license.

B. if $0 < m \leq (2n^2 + 1)/2(2n + 1)$, then $\Delta W(m) < \Delta\prod(m,n)$: with sufficiently few licenses sold, the social value of the *m*th license is less than the lab's profit from the license.

C. if $n \geq 3$, then $\Delta W(1) < \Delta\prod(1,n)$: if there are three or more firms in the downstream market, the social value of the first license is less than the lab's profit.

Proof: Begin with part B: Solving for the license m such that $\Gamma = 0$ obtains $[C_H - C_L + 2n(1 - C_L)]/2[(C_H - C_L)\cdot(1+2n)] \equiv m^*$. As $\partial\Gamma/\partial m > 0$, $m < m^* \Rightarrow \Gamma < 0$ (the social value of the m^{th} license is less than the lab's profit from the license). As $\partial m^*/\partial C_H < 0$, $m < m^*(\bar{C}_H) \Rightarrow \Gamma < 0\ \forall\ C_H$. $m^*(\bar{C}_H) = (2n^2 + 1)/2(2n + 1)$. Part C follows because $\partial m^*(\bar{C}_H)/\partial n > 0$ and at $n = 3$, $m^*(\bar{C}_H) > 1$. A: Since $\partial m^*/\partial C_H < 0$, then $m^*(\bar{C}_H/2) > n - 1 \Rightarrow m^* > n - 1$ for all $C_H < \bar{C}_H/2$. (It is straightforward to show that $m^*(\bar{C}_H/2) > n - 1$: since $\partial m^*(\bar{C}_H/2)/\partial C_L > 0$, then if $m^*(\bar{C}_H/2) > n - 1$ at $C_L = 0$, $m^*(\bar{C}_H/2) > n - 1$ for all C_L. At $C_L = 0$, $m^*(\bar{C}_H/2) = (1 + 4n^2)/2(1 + 2n) > n - 1$ for positive n.) //

Lemma 1: If $\Delta\prod(m,n) > \Delta W(m)$ for all $m < n$. then

A. there exists a fixed cost f such that the profit maximizing number of licenses (m^{Π}) is strictly greater than the welfare maximizing number of licenses.

B. there is no f such that profit maximizing number of licenses is strictly less than the welfare maximizing number of licenses.

Proof: It is first useful to define $\Delta\prod^G(m,n) = \Delta\prod(m,n) + f$ as the profit of an additional license gross of fixed costs and $\Delta W^G(m) = \Delta W(m) + f$ as the social welfare of an additional license gross of fixed costs. Note that $\Delta\prod(m,n) > \Delta W(m)$ if and only if $\Delta\prod^G(m,n) > \Delta W^G(m)$. If $\Delta\prod^G(m,n) > \Delta W^G(m)$ for all $m < n$, then since $\Delta W^G(m) > 0$, $\Delta\prod^G(m,n) > 0$ for all $m < n$. Thus, since $\partial\Delta\prod/\partial f < 0$ for each $m < n$ there is an $f > 0$ (denoted $f(m)$) such that that m is the profit maximizing m (specifically, starting at $f = 0$, f can be increase until $\Delta\prod^G(m+1,n) - f < 0$, but $\Delta\prod^G(m,n) - f > 0$). Since $\partial\Delta W(m)/\partial f = \partial\Delta\prod(m,n)/\partial f < 0$ and $\Delta\prod^G(m,n) > \Delta W^G(m)$, then either $\Delta W^G(m) - f(m) < 0$ or there exist $f' > f(m)$ such that $\Delta\prod^G(m,n) - f' > 0 > \Delta W^G(m) - f'$. Finally, since $\partial\Delta W(m)/\partial m < 0$, then $\Delta W(m+1) - f(m) < 0$. Hence, at either $f(m)$ or f' the lab's licensing is socially excessive. Part B. follows trivially from the condition.//

Lemma 2: If $\Delta\prod(m,n) > \Delta W(m)$ for all $m < m'$, $m' \geq 1$, then there is a fixed cost f such that the profit maximizing number of licenses (m^{Π}) is strictly greater than the welfare maximizing number of licenses.

Proof: Since $\Delta\prod(1,n) > 0$ if $f = 0$, then if $\Delta\prod(m,n) > \Delta W(m)$ for all $m < m'$, then by the proof of lemma 1, there exists an f such that $\Delta\prod(1,n) > 0 > \Delta W(1)$. As $\partial(\Delta W(m))/\partial m < 0$ any additional license would only lower welfare further.//

Proposition 2: If $\{x = 1$ and $n \geq 4\}$ or $\{x = 2$ and $n \geq 5\}$, then $\Delta W(1) < \Delta\prod(1,n)$: If a downstream firm owns the lab and there are at least four downstream firms, or if two firms own the lab and there are at least five firms, then the social value of the first license is less than the lab's profit.

Proof: $\Delta W(m) - \Delta\prod(m,n,x) = (C_H - C_L)\Gamma/2b(n+1)^2$, $\Gamma \equiv (C_H - C_L)(-1+2m-2x-4xm+4mn) + (4x-2n)(1-C_L)$. If $m = 1$, then $\partial\Gamma/\partial C_H > 0$ at $\{x = 1$ and $n \geq 4\}$ or $\{x = 2$ and $n \geq 5\}$; $\Gamma < 0$ at $\bar{C}_H$.//

Proposition 3: With a lab that is owned by downstream firms (*RJV*),

A. $\partial[\Delta W(m) - \Delta\prod(m,n,x)]/\partial x > 0$: as more firms own the lab the social value of the m^{th} license increases relative to its private value.

B. if $x \geq n/2$, then $\Delta\prod(m,n,x) < \Delta W(m)$: if more than half of the firms belong to the RJV, then the social value for the m^{th} license exceeds the RJVs profit from the license.

Proof: $\Gamma \equiv (C_H - C_L)(-1+2m-2x-4xm+4mn) + (4x-2n)(1-C_L)$. As $(C_H - C_L)/2b(n+1)^2 > 0$ for $C_H \in (C_L, \bar{C}_H)$, $\text{Sgn}[\partial[\Delta W(m) - \Delta\prod(m,n,x)]/\partial x] = \text{Sgn}[\partial\Gamma/\partial x] = \text{Sgn}[2(-C_H + 2C_L m - 2C_H m - C_L + 2)]$ for

$C_H \in (C_L, \bar{C}_H)$. Since $\partial[-C_H + 2C_L m - 2C_H m - C_L + 2]/\partial C_H < 0$ and $[-\bar{C}_H + 2C_L m - 2\bar{C}_H m - C_L + 2] > 0$, $[2(-C_H + 2C_L m - 2C_H m - C_L + 2)] = \partial\Gamma/\partial x] > 0\ \forall\ C_H$ and hence $\partial[\Delta W(m) - \Delta\prod(m,n,x)]/\partial x > 0$. At $x = n/2$ the $\Delta W(m) - \Delta\prod(m,n,x) = (C_L - C_H)^2(2m-1)/2b(n+1) > 0$. //

<u>Proposition 4</u>: A. If $n \geq 4$, then $v(1) > \Delta W(1)$: A downstream firm's profit from having the only license is greater than its social value when there are four or more firms.

B. If $n \geq 2$ and $m \geq 2$, then $v(m) > \Delta W(m)$: A downstream firm's profit from other than the first license is greater than the social value, independent of the number of firms.

C. $\partial[\Delta W(m) - v(m)]/\partial m < 0$: as more licenses are issued, the social value of the license decreases relative to the downstream profit.

Proof: $\Delta W(m) - v(m) = (C_H - C_L)\gamma/2b(n+1)^2$, where $\gamma \equiv [(C_H - C_L)(-6m+1+4n) + (2n-4)(C_L - 1)]$. First, $\partial\gamma/\partial m < 0$ (which proves part C.) and $\partial\gamma/\partial n < 0$ for $C_H \in (C_L, \bar{C}_H)$ (since $\partial\gamma/\partial n < 0$ at $\bar{C}_H$ and $\partial^2\gamma/\partial n\partial C_H > 0$). Since $\gamma < 0$ at $m = 1$ and $n = 4\ \forall\ C_H$, then $\gamma < 0$ for $m \geq 1$ and $n \geq 4$. Likewise, since $\gamma < 0$ at $m = 2$ and $n = 2\ \forall\ C_H$,, then $\gamma < 0$ for $m \geq 2$ and $n \geq 2$.//

<u>Proposition 5</u>: With an independent lab that uses the price strategy and $n > 2$

A. if $C_H \leq 6\bar{C}_H/13$, then $\Delta W(m) < \Delta\prod^P(m,n)$ for $m < n$: with a sufficiently small cost innovation, the social value of a license is less than the lab's profit from the license.

B. if $0 < m \leq (2n^2 - 4n - 1)/2(2n - 3)$, then $\Delta W(m) < \Delta\prod^P(m,n)$: with sufficiently few licenses sold, the social value of the mth license is less than the lab's profit from the license.

C. if $n \geq 4$, then $\Delta W(1) < \Delta\prod^P(1,n)$: if there are four or more firms in the downstream market, the social value of the first license is less than the lab's profit.

<u>Proof</u>: $m^* = [C_H - C_L + 2(n-2)(1 - C_L)]/[2(C_H - C_L)(2n-3)]$ and $m^*(\bar{C}_H) = (2n^2 - 4n - 1)/2(2n - 3)$. The proof then follows the proof of proposition 1 except that $6\bar{C}_H/13$ is the upper bound.//

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Figure 1