The Unilateral Incentives for Technology Transfers:

Predation by Proxy [§]

Anthony Creane[†] and Hideo Konishi[‡]

In 1984 GM and Toyota began the joint production of automobiles to much controversy over its anti-competitive effects. The argument for the joint production was the considerable efficiency gains GM would obtain. Since then, the anti-trust controversy has died, but a question remains: why would the most efficient manufacturer (Toyota) transfer to its largest rival the knowledge to transform itself into a very efficient rival? We examine when such transfers could be unilaterally profitable, finding that it can serve as a credible way to make the market more competitive, forcing high cost firms to exit (or preventing future entry). This is not without a cost to Toyota since such a transfer also makes the remaining rivals more efficient. Despite this, we find a sufficient (but not necessary) condition for it to be profitable to predate "by proxy": the market satisfies an entry equilibrium condition. Further, we find that it is then optimal to predate on every firm that is vulnerable and so a market with many firms can become a duopoly. Profitable predation implies higher prices, to the detriment of consumers. Yet the improved production efficiency outweighs this loss, resulting enhanced social welfare. In contrast, profitable *non-predatory* joint production (or technology transfers) may reduce welfare. Paradoxically, the potential for predation could encourage entry ex ante.

JEL: D4, L1, L41
Key words: Predation, Technology Transfers

[†]Michigan State University
[‡]Boston College

[§] We are grateful to Jay Pil Choi for his comments on a preliminary version of this paper.

"*If this joint venture between the world's first and third largest automobile companies does not violate the antitrust laws, what does the Commission think will?*" – FTC Commissioner Bailey

"*[B]attalions of neo-classical economists dancing on the head of a pin cannot obscure the threat that this marriage of competitors poses to the American consumer…*" – FTC Commissioner Pertschuk, *General Motors Corp.*, 104 F.T.C. at 391, 397 (1984)

1. Introduction

In 1984 General Motors (at the time the world's largest automaker) and Toyota (number three) began joint production of vehicles at the New United Motors Manufacturing Inc. (NUMMI) in Fremont, California. Into this partnerships GM provided the plant and infrastructure while Toyota provided the platform, input supplier structure and ran the plant. Perhaps most importantly Toyota provided its knowledge of production, which was and is well known for its quality and low cost, for GM to emulate (Teresko 2006).[1]

The issue was controversial at the time as the FTC split on their decision allowing the joint production, giving permission for only twelve years, and had three years earlier denied a joint production venture between Yamaha and Brunswick (Fenton 2005). Among the most vocal opponents of the FTC's granting permission were Ford and Chrysler, while some economists argued to the FTC that its anticompetitive effect was "both probable and substantial" (Fenton 2005). This debate continued beyond NUMMI and was part of the general question regarding collaboration between firms (see, e.g., the symposium in the Summer 1990 issue of the *Journal of Economic Perspectives* and in particular Shapiro and Willig's article on production joint ventures).

Since then the restrictions on joint production have diminished considerably as the National Cooperative Production Amendments (NCPA) were passed in 1993 and the same year the FTC, to little fanfare, allowed NUMMI to continue indefinitely (*General Motors Corp*., 116 F.T.C. 1276 1993). Part of the reassessment of joint production likely reflects the contemporaneous reassessment

[1] Indeed, two of the main reasons the FTC allowed NUMMI were that production costs would be lower and that the venture would give GM the chance to learn and use "Toyota's efficient manufacturing and management methods."

of mergers between firms since, without efficiency gains, mergers are unlikely to be profitable unless a monopoly results (Salant et al. 1983), and even then such a coalition is unlikely to be stable (Kamien and Zang 1990). In addition, authorities when allowing joint production normally impose conditions so as to make collusion difficult.[2]

While the policy aspect of joint production has been seemingly resolved, Toyota's involvement with NUMMI still seems quite surprising: it was giving its largest rival the potential to make huge gains in efficiency.[3] First, Toyota was not forced into the joint production as both Honda and Nissan had independent plants in the US before NUMMI started production, and all of Toyota's future plants would be independent. Second, even if Toyota received some benefit from reduced fixed costs, the potential loss in market share and profits to a more efficient GM would seemingly out-weigh such benefit. Finally, this situation is not unique as there are other examples of industry cost leaders freely transferring their knowledge to major rivals through joint production.[4]

In this paper we examine when a firm would agree to engage in such a technology transfer and explore its welfare effects.[5] While there is a good deal of work examining when technology transfers are jointly profitable (e.g., the licensing literature), we are interested in when Toyota would benefit from transferring its technology to a rival when it does not receive any payment. The key is that the technological gains from joint production (a more efficient GM) will affect the equilibrium

---

[2] For the consent agreement with the FTC "Toyota, GM and the joint venture were prohibited from communicating on pricing, design, and sales except as necessary for the operation of the joint venture. Personnel of GM, Toyota, and the venture were required to keep copies of written communications and logs of nonwritten communications among one another. The FTC had inspection and visitation rights" (Fenton 2005).

[3] In North American assembly plant productivity, Toyota had 22.05 hours of plant labor per vehicle assembled in 2006, while GM had 22.15 hours as GM "virtually matched Toyota" in productivity "for the first time since it has been measured" (Merx 2007). Although, there is still a debate as to the extent that GM did learn from Toyota.

[4] In the steel industry USX engaged in joint production with Kobe Steel so as to gain efficiency (Cullison 1989). In the food industry Heinz hoped to learn from Kagome (Japanese) regarding its expertise in vegetable juice packaging through joint production. Interestingly, Kagome's stock price closed up on the day of the announcement and had been rising all year on rumors of the venture (Smith 2001).

[5] Other aspects of joint production have been examined in Chen and Ross (2000), who focus on how joint production can be offered by a monopoly incumbent to a potential entrant to prevent full scale entry by the entrant ad Bloch (1995) who examines the formations of associations to lower marginal costs, but begins instead with symmetric firms and a given association reduces all of its members' costs equally.

price, which normally would harm Toyota. However, when exit is possible, it also could drive out rival firms (or prevent entry), which could benefit Toyota. Despite the harm from having a more efficient rival, we find that the latter effect can dominate. It can be profitable for Toyota to predate "by proxy" through joint production. NUMMI, then, could indeed have anti-competitive effects, but in the form of predation rather than that of collusion. This is novel type of 'predation' tactic as a firm benefits by lowering – rather than raising – its rival's costs (Salop and Scheffman 1983). This tactic can arise here, unlike in most previous models of predation, because the predator here faces multiple rivals instead of just one.[6]

We begin by considering which partner among its heterogeneous rivals the predator would choose. An immediate result is that the least efficient firm is never the partner, as this firm is the most vulnerable firm. Second, there is a trade-off facing a potential predator: it wants its partner's cost reduction to be large enough to induce the predation, but not so large that the predator is harmed by the more efficient rival it has created. Despite these conflicting requirements for profitable predation, predation by proxy can occur and result in a significant change in the market structure: for example, from many rivals to a duopoly.

To better place these trade-offs in context of the literature, we then consider this predation in a commonly used framework: there is a firm with a superior technology facing rivals that use a lesser one. In addition to the classic dominant firm model, this is also a standard framework in the licensing literature (e.g., Katz and Shapiro 1985 and Kamien and Tauman 1986). We show that predation by proxy is always profitable when there is free entry of the less efficient firms. However, the result does not rely on the preyed upon firms being marginally profitable as the entry condition is sufficient but not necessary. Second, we find that the predator will drive out *every* rival it can; it is never optimal to only drive out a few firms when you can drive out many (proposition 2) even

---

[6] For example, see the work surveyed in Ordover and Saloner (1989) and in Genesove and Mullin (1997, 2006).

though the predator must make the remaining rivals increasingly efficient to drive out additional firms. This implies that if a predator can prey to a duopoly, it will, and so ex post there may be no firms with the lesser technology. Thus, there was a basis for the concern regarding the anti-competitive effects of joint production. Another implication is that in the classic dominant firm model, the dominant firm may prefer to transform some of the fringe firms into near equals to drive out the remaining firms so that no fringe exists in equilibrium. Finally, there is an indeterminacy in how the predation occurs: the predator acts by lowering the average of the marginal cost, but is indifferent as to how that occurs, e.g., by transferring to one surviving rival the necessary cost reduction or to two surviving rivals a half sized cost reduction.

We then characterize the welfare effects of predation. On one hand, predation only occurs if it is profitable to the predator. In addition it creates a positive externality for those firms that receive the transfers. However, profits are lost from those firms that are driven out, and so the impact on producer surplus is not immediate. To put it differently, the predator is maximizing its own profits and not aggregate profits. In addition, profitable predation implies a higher equilibrium price ex post and so consumers are clearly worse off. Hence, there is a rationalization for the original concern regarding consumer welfare. However, the gains in production efficiency will always offset this loss, resulting in enhanced social welfare (proposition 3). Thus, while predation by proxy has anti-competitive effects as it drives out competitors and raises the price, on the whole it is welfare improving. Finally, we consider the effects on aggregate profits of the less efficient firms and show that aggregate profits may increase. This implies that the FTC, by allowing for joint production that could be predatory, may actually be encouraging entry into a market.

In the next section we present the basic assumptions. In section 3, we derive conditions for predatory joint production pairings to be profitable for the more efficient firm when it receives no direct cost benefit. In section 4, we analyze the incentives for an industry leader to predate on its rivals and section 5 concludes.

2. The Model

As we are examining joint production, the basic Cournot market structure is a natural starting point. There is a commodity besides a numeraire good, and its demand curve is linear and is normalized

$$p(Q) = 1 - Q$$

if $Q \leq 1$ and $p(Q) = 0$ otherwise. There are $K > 2$ firms in the industry, but it may not be the case that all firms stay in the market. If (predicted) net profit is negative, a firm would exit from the market. That is, for ease it is assumed that if a firm is indifferent between staying and exiting, it exits.

Firms are indexed as $k \in \{1,2,...,K\}$ with $k = 1$ being the most efficient firm. With a little abuse of notation let the set $\{1,2,...,K\}$ be denoted by K. We assume that firms have constant marginal costs $c_k \in [0,1)$. We assume that there is a common fixed (annual) operational cost $F > 0$. Each firm k's production level is denoted by q_k, and its strategic variable is quantity of production. Firm k's profit function is written as:

$$\begin{aligned} \pi^k(q_k, q_{-k}) &= (1 - Q - c_k)q_k \\ &= (1 - \textstyle\sum_{k'=1}^{K} q_{k'} - c_k)q_k, \end{aligned}$$

where $Q = \sum_{k'=1}^{K} q_{k'}$ and we assume $Q \leq 1$ for the analysis to be relevant. The first order condition for profit maximization (assuming interior solution) is

$$\frac{\partial \pi^k}{\partial q_k} = (1 - Q - c_k) - q_k = 0.$$

Summing the first order conditions for all K firms, we obtain

$$K - (K+1)Q - \sum_{k'=1}^{K} c_{k'} = 0,$$

or

$$Q(K) = \frac{K}{K+1} - \frac{K}{K+1}\bar{c}(K),$$

Where $\bar{c}(K) = \frac{1}{K}\sum_{k'=1}^{K} c_{k'}$ and $Q(K)$ denote the average marginal cost and equilibrium aggregated output level when there are K firms. Similarly, we denote equilibrium price with K firms by $p(K) = 1 - Q(K)$. Firm k's output when K firms are present in the market is

$$\begin{aligned} q_k(K) &= 1 - Q(K) - c_k \\ &= \frac{1}{K+1} + \frac{K}{K+1}\bar{c}(K) - c_k. \end{aligned}$$

Note that our interior solution presumption requires ($c_K > c_1$),

$$p(K) = \frac{1}{K+1} + \frac{K}{K+1}\bar{c}(K) > c_K$$

This condition plays roles in characterizing the equilibrium. Note also that if this condition is violated, then firm K does not produce in equilibrium ($q_K(K) = 0$). Thus, without loss of generality, we can assume an interior solution.

Firm k's net profit is written as

$$\pi_k(K) = \left(\frac{1}{K+1} + \frac{K}{K+1}\bar{c}(K) - c_k\right)^2 - F = (p(K) - c_k)^2 - F.$$

We now present a lemma characterizing the market when there are K firms producing, which will be useful for our analysis.

Lemma 1. Assume interior solutions. Then, for all $K = 2,3\ldots$, we have

1. $\pi_k(K) \geq \pi_{k+1}(K)$ for all $k \in \{1, \ldots, K-1\}$

2. $Q(K-1) < Q(K)$

3. $p(K-1) > p(K)$

4. $q_k(K-1) > q_k(K)$ for all $k \in \{1, \ldots, K-1\}$

5. $\pi_{K\text{-}1}(K-1) > \pi_K(K)$.

The proof to the lemma can be found in the appendix.

3. Joint Production as Profitable Predation

We begin our analysis of predation by examining which rival firm would a predator choose to transfer it technology. For example, Toyota potentially had three US firms to choose from, with varying levels of efficiency and possible gains from Toyota's knowledge. Other examples include Kobe Steel which chose USX, and Kagome which choose Heinz, to share their knowledge through joint production. More generally, joint production usually is between two firms (not more), which may reflect the fact that the transaction costs of such operations are non-trivial.[7,8]

We assume that joint production is a purely technological action; the firms do not coordinate on their production through the joint production. There are several reasons for this. To begin with, as discussed in the introduction, government policy disallows such collusion; independent production is typically a condition for a joint venture. For this reason it is assumed that revenue transfers between the firms cannot occur. Second, and perhaps more importantly, it is well known (Salant, et al. 1978) that in the setting here firms are almost always worse off if they do collude, and even if they are better off the coalition is unlikely to be stable (Kamien and Zang 1990). Finally, our focus is on

[7] In addition to these examples, Ford and Fiat have planned joint production in Poland (and there are many examples automobile industry in general); Phillips (Dutch) and Microelectronics (French) have a joint silicon chip plant in France; Toshiba (Japanese) and SanDisk (US) jointly produce flash memory in Virginia; and Samsung (Korea) and Sony jointly produce flat screens in Korea.

[8] Teece (1976) finds that when technology is transferred through licensing, the transfer costs are on average 19% and as much as 59% of total costs. 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." See also Boldrin and Levine's (2004) theoretical arguments for why ideas are rivalrous.

whether a firm can unilaterally benefit from joint production even if it cannot be used to induce profitable collusion (i.e. the monopoly outcome). Thus, we analyze the implications of the cost changes only and take each firm's production as being set independently.[9]

Suppose now that two arbitrary firms, k and k', with $c_k \leq c_{k'}$, engage in a joint production. The cost-reducing joint production gives benefits Δ_k and $\Delta_{k'}$ with $\Delta_k \leq \Delta_{k'}$. For example, the marginal cost of firm k' is now $c_{k'} - \Delta_{k'}$. Since we are interested in joint production as a purely predatory device, *we will assume that the predator receives no cost reduction, i.e., if firm j is the predator, then $\Delta_k = 0$ in the rest of the paper*. It is easy to see that if $\Delta_k = 0$ and if the number of firms in the market is fixed, then there is no incentive for a low cost firm to engage in a technology transfer to a high cost firm: the market price ($p(K)$) will decrease as a result of the high cost firm's marginal cost decreasing. However, once we allow for the possibility of exit, the market price could, instead, increase. Thus, we assume a two stage game *after joint production decision has been made*: in stage 1, firms choose if they stay in the industry or not, and in stage 2, the firms that stayed in the industry play a Cournot game.

A joint production effectively lowers the marginal cost of firm k', and thus the average marginal cost $\overline{c}(K)$. This reduces the third party firms' net profits. To see this, recall that a firm j's profit is

$$\pi_j(K) = \left(p(K) - c_j\right)^2 - F = \left(\frac{1}{K+1} + \frac{K}{K+1}\overline{c}(K) - c_j\right)^2 - F .$$

This implies that as $\overline{c}(K)$ is reduced, all other firms' net profits decrease, and some firms may have negative net profits if the number of firms (K) is intact. Let us focus on the highest cost firm, which for clarity we will denote K (for notational simplicity, assume $k' \neq K$). Before the joint production by

[9] In our companion paper (Creane and Konishi 2007) we examine the general conditions for joint production to be profitable when firms are heterogeneous.

k and k', K earned positive net profits:

$$\pi_K(K) = \left(p(K) - c_K\right)^2 - F \geq 0.$$

After the joint production, the average marginal cost decreases to $\overline{c}(K) - \left(\Delta_{k'} / K\right)$. Thus,

$$p^J(K) - c_K = p(K) - \frac{\Delta_{k'}}{K+1} - c_K < \sqrt{F} \leq p(K) - c_K, \tag{1}$$

the joint production drives firm K out, and the number of firms in the market goes down to $K\text{–}1$ (unless more firms want to exit). Note that in (1) $p^J(K) = p(K) - \Delta_{k'} / (K+1)$ is the market price *with K firms* after the technology transfer. As firm K's profit margin falls under the threshold level $\sqrt{F}$, firm K can no longer survive in the market and there is now a second benefit to firms k and k' from the joint production as the market price with $K\text{-}1$ firms is greater than the one with K firms: $p^J(K-1) > p^J(K)$. Thus,

Lemma 2. Under condition (1), a joint production between firms k and k' drives firm K out of the market, and improves both firms' profits more than the case of a fixed number of firms.

If (1) holds, that is, the two firms by engaging in joint production are able to drive out at least firm K, then even though firm k received no direct benefit ($\Delta_k = 0$), it still would engage in joint production if the price increase from firm K's exit is sufficiently great, i.e., $p^J(K-1) > p(K)$. That is, a sufficient condition for firm k's profit to increase (given non-negative $\Delta_{k'}$) is that the market price increases, which occurs if

$$p^J(K-1) - p(K) = \frac{1}{K} + \frac{K-1}{K}\left(\overline{c}(K-1) - \frac{\Delta_{k'}}{K-1}\right) - \frac{1}{K+1} - \frac{K}{K+1}\overline{c}(K)$$

$$= \frac{1}{K} + \frac{1}{K}\sum_{\tilde{k}=1}^{K-1} c_{\tilde{k}} - \frac{\Delta_{k'}}{K} - \frac{1}{K+1} - \frac{1}{K+1}\sum_{\tilde{k}=1}^{K} c_{\tilde{k}}$$

$$= \frac{1}{K(K+1)}\left(1+\sum_{\tilde{k}=1}^{K} c_{\tilde{k}}\right) - \frac{c_K + \Delta_{k'}}{K}$$
$$= \frac{1}{K}\left(p(K) - \left(c_K + \Delta_{k'}\right)\right) > 0.$$

Note that this condition is necessary and sufficient to get a price increase. That is, the profit of firm *k* is improved by a joint production that induces the K^{th} firm to exit if and only if we have

$$\Delta_{k'} < p(K) - c_K \tag{2}$$

Thus, we have a set of conditions for the firms to engage in joint production.

Proposition 1. Under conditions (1) and (2), a joint production between firms k and k' drives at least firm *K* out of the market, and improves profits of both firms.

To provide some insight to our conditions, we note that nested within our model is a commonly used environment (particularly in the licensing literature): there is a single firm with superior technology that chooses whether to share its superior technology in its entirety with a rival. Likewise, an expressed purpose of NUMMI was for GM managers, workers, etc. to learn Toyota's superior production methods by working in a Toyota run plant and so Toyota may not have been able to control the amount of the transfer. For the model here that implies that $\Delta_{k'} = c_{k'} - c_k$. (A difference is that in the licensing literature it is a question of raising joint profits.) In this environment, to *which* rival would an efficient firm want to transfer its technology? To begin with, it is immediate that we do not expect to see joint production with the weakest firm (firm *K*), as this would be the easiest target for predation, although this may not be true if the objective were entry deterrence.[10] In fact, the predator would want to pick the firm most like itself as possible as condition (2) becomes

---

[10] We show in Creane and Konishi (2007) that when the objective is to maximize instead the joint profits of the two firms, the efficient firm will not choose the least efficient firm in that case either.

$$c_k - c_{k'} < p(K) - c_K .$$

It is clear then that the two conditions are somewhat contradictory. Condition (1) requires that the cost savings for firm k' from the joint production is large enough to drive (at least) firm K out of the market, while condition (2) requires that this same cost savings is small enough so that equilibrium price rises after the firm(s) exit. One may wonder if the two conditions result in the empty set, or if at most only one marginal firm may be driven out. We close this section with the following example to demonstrate this is not the case.

Example 1: Unilateral technology transfer that drives out many rivals

There is a low cost firm and multiple high cost firms. Let the low cost firm have marginal cost c_L = .42 and, for ease of calculation, all other firms have identical marginal costs c_H = .6. In addition, let fixed cost of operations be $F = 1 \times 10^{-4}$. It is straightforward to verify that up to twenty-one firms may operate profitably (K = 21). If there are twenty firms and the efficient firm engages in joint production with one high cost firm (k') so that $\Delta_{k'} = c_H - c_L$, then the other eighteen firms exit the market and the low cost firm's profits are greater. However, this transfer need not always be profitable. For example, if the low cost firms costs are slightly lower, c_L = .41, then the transfer would drive out the rivals, but the efficient firm's profits would be greater without the transfer (i.e., with nineteen less efficient competitors than one efficient competitor).

Thus, to the extent predation is viewed as anti-competitive, joint production can be significantly anti-competitive, potentially changing a market from one with many firms to a duopoly.

4. Purely Predatory Joint Production

In Example 1, we saw that a more efficient firm may be able to profitably drive out a large number of firms by sharing its technology with a single rival. However, the example also raises several questions about when predation will occur since it was not profitable when c_L = .41. For example, if the predator is not restricted to making only complete transfers, i.e., it could make a partial transfer ($\Delta_{k'} < c_H - c_L$), then perhaps the predator could find predation profitable when c_L = .41.[11] If so does that imply that a firm that can predate on its rivals through joint production, will always choose to do so – did GM's rivals have a reason to be nervous?

A second question is, even if *some* predation is always profitable, what is the profit-maximizing number of firms to predate – does a firm predate on *every* firm it can? In the previous example, the more efficient firm could drive out eighteen rivals, but would it want to, or would it only drive out half of its rivals? After all, to drive out additional rivals (which raises the ex post price) requires making the remaining firms more efficient (which harms the predator). A related issue is whether the number of initial rivals affects the level of predation. That is, if there are nineteen rivals could it be that the efficient firm preys on eighteen of them, but if there are only three rivals operating initially, then the efficient firm makes no technology transfer? In this case to drive out the third firm would take a larger discrete transfer than it would if the predator had made transfers to drive out the first seventeen firms. Finally, a natural question is the *modus operandi* of predation: does the predator prefer to make a large technology transfer to a few firms or to make small transfers to many firms?

A third question is the welfare effects of predation. The driving concern among members of the FTC when considering the potentially anti-competitive nature of NUMMI, was its affect on US consumers and the US welfare. If joint production can profitably serve as a type of predation and drives out rivals, then there is some basis for their concern. Does predation improve social welfare? How about consumer surplus and the profit of the industry overall? If social welfare improves by predation, is it a general result, or do we need some condition? In particular does the predator's

[11] It is arguable that despite the presence of GM workers and managers at NUMMI, Toyota may have been able to shield some of their most valuable knowledge.

modus operandi affect the welfare conclusion?

Given the generality of our structure these questions can be answered in countless ways: there are many possible joint production pairings and a firm could choose multiple partners. To give context to the answers we will use the standard model of a technology superior firm facing less efficient rivals (e.g., in the licensing literature) rather than cataloging a laundry list of possibilities. That is, we assume there is an efficient firm that faces $K - 1$ less efficient firms ($c_1 = c_L < c_2 = c_3 = \ldots = c_K = c_H$). Further, for any $k > 1$, firm k's technology is worthless for firm 1 ($\Delta_1 = 0$), while firm k's marginal cost of production can be reduced by adopting some or all of firm 1's technology through joint production. It is natural (although not necessary) to assume that the maximum cost reduction firm k can obtain equals $c_k - c_L = c_H - c_L$. Let $c_k^{'} \in [c_L, c_H]$ be firm *k's* marginal cost of production after firm 1 transfer its technology to firm *k.*

Let $\widehat{K}$ be the number of firms that remain after firm 1 has made all of its technology transfers, i.e. given a cost structure represented by the vector $(c_1, c'_2, \ldots, c'_k, \ldots, c'_{\widehat{K}})$ (which may include a transfer to firm $\widehat{K}$ + 1). This requires that firm $\widehat{K}$ + 1 prefers to exit, that is

$$\sqrt{F} \geq \frac{1}{\widehat{K}+2} + \frac{\sum_{k=1}^{\widehat{K}+1} c_k^{'}}{\widehat{K}+2} - c_{\widehat{K}+1}^{'}.$$

where $c_k' \in [c_L, c_H]$. With the framework established, we will now turn to the specific questions.

4.1 Conditions for predation to occur

Firm 1's objective is to maximize its profits, and a useful proxy for firm 1's profit in this Cournot setting is its output

$$q_1(c^{'}) = \frac{1}{K+1} + \frac{\sum_{k=1}^{K} c_k^{'}}{K+1} - c_L.$$

Thus, a small K and high $\sum_{k=1}^{K} c_k^{'}$ increases firm 1's profits. (Note that $Kc \leq \sum_{k=1}^{K} c'_k \leq \sum_{k=1}^{K} c_k$

holds.) Obviously then, so as to maximize $\sum_{k=1}^{K} c_k^{'}$ it would not transfer any technology to firm $\widehat{K}+1$: $c_{\widehat{K}+1}^{'} = c_{\widehat{K}+1} = c_H$. Thus, if firm 1 through predation wants to push firm $\widehat{K}+1$ out it will choose the largest $\sum_{k=1}^{\widehat{K}} c_k^{'}$ to achieve this so as to maximize $q_1(c^{'})$ (i.e., the $\sum_{k=1}^{\widehat{K}} c_k^{'}$ such that firm $\widehat{K}+1$ just exits):

$$\sqrt{F} = \frac{1}{\widehat{K}+2} + \frac{\sum_{k=1}^{\widehat{K}+1} c_k^{'}}{\widehat{K}+2} - c_{\widehat{K}+1}$$
$$= \frac{1}{\widehat{K}+2} + \frac{\sum_{k=1}^{\widehat{K}} c_k^{'}}{\widehat{K}+2} - \frac{\widehat{K}+1}{\widehat{K}+2} c_H,$$

Hence, the optimal $\sum_{k=1}^{\widehat{K}} c_k^{'}$ is

$$\sum_{k=1}^{\widehat{K}} c_k^{'} = (\widehat{K}+2)\sqrt{F} + (\widehat{K}+1)c_H - 1.$$

The first question is: what is the most firms the low-cost firm could drive out with predation? Since from above the $\widehat{K}+1$ firm exits if

$$c_H = \frac{1}{\widehat{K}+1} + \frac{\sum_{k=1}^{\widehat{K}} c_k^{'}}{\widehat{K}+1} - \frac{\widehat{K}+2}{\widehat{K}+1}\sqrt{F},$$

then we could define the lowest possible number of firms that could remain after such transfers (denoted as $\underline{K}$) by

$$c_H \geq \frac{1}{\underline{K}+1} + \frac{\underline{K}c_L}{\underline{K}+1} - \frac{\underline{K}+2}{\underline{K}+1}\sqrt{F},$$

that is, firm $\underline{K}+1$ exits, if the technology is transferred to $\underline{K}$ of the firms, and

$$c_H < \frac{1}{\underline{K}} + \frac{(\underline{K}-1)c_L}{\underline{K}} - \frac{\underline{K}+1}{\underline{K}}\sqrt{F},$$

that is, that firm $\underline{K}$ does not exit if the technology is transferred to $\underline{K} - 1$ firms.

Though the low cost firm can drive out $K - \underline{K}$, it must make its rivals more efficient to do this, which harms the efficient firm. The next question then is whether it would want to drive out the $K-\underline{K}$ firms. Since the minimum average cost that drives out the $\widehat{K}+1$ firm is

$$\sum_{k=1}^{\widehat{K}} c_k' = (\widehat{K}+2)\sqrt{F} + (\widehat{K}+1)c_H - 1,$$

then given that predation is feasible, firm 1's profit maximization problem can be written as,

$$\max_{k\in\{\underline{K},\ldots,K-1\}}\left(\frac{1}{k+1} + \frac{(k+2)\sqrt{F}+(k+1)c_H - 1}{k+1} - c_L\right), \text{ or}$$

$$\max_{k\in\{\underline{K},\ldots,K-1\}}\left(\frac{(k+2)\sqrt{F}}{k+1} + c_H - c_L\right).$$

As is easily seen, the first term of the contents of the above parenthesis is decreasing in *K*. Hence, the solution is clearly $\underline{K}$ and we conclude with:

Lemma 3. Suppose that $c_L = c_1 < c_2 = c_3 = \ldots = c_K = c_H$ and that the efficient firm can predate on *m* firms. Then, if predation on any firm is profitable, it is profit maximizing to predate on all *m* firms. The market equilibrium has $K-m$ firms with at least one firm more efficient.[12]

While it makes intuitive sense that if there were a marginal firm just earning positive profits, then by making a small technology transfer the predator can drive the firm out with little cost, Lemma 3 indicates that it is not just marginal firms that will be driven out. This is surprising since the predator may have to give a large technology transfer to drive out the last firm, making the recipient of the transfer a strong rival. Despite this, it is always more profitable to predate on every

---

[12] Note that while we have been considering predation, with a slight change in interpretation the results could be applied to entry deterrence. For example, if the perception in the early 1980s was that the US auto industry would so lose its protection, then Toyota would have expected additional entrants. In that case, we could modify the timing of our model slightly and interpret *K* as the number of firms that will eventually enter into the market. However, before the additional entry has occurred the efficient firm could choose a rival to transfer its technology to deter the additional entry. Thus, Toyota's involvement in NUMMI could have been also to deter entry, or if entry occurred lead to a smaller scale.

possible firm rather than just a few. For instance, if the efficient firm (with c_L = .42) could predate to a duopoly (as in the Example), then it always will rather do that than just drive out one or two firms. The market structure will have the fewest firms that predation will allow.

On the other hand, Lemma 3 might seem surprising given the example when the efficient firm had slightly lower marginal costs (c_L = .41): it was no longer profitable to predate to a duopoly. However, recall that the predator was restricted to making only a complete technology transfer, while here a partial technology transfer is possible. In fact, it is straightforward to verify, that if the predator makes a slightly smaller transfer (.17) to an inefficient firm, then a duopoly still results, but in this case the predator's profits are greater with the duopoly than with the original market structure. More importantly, the minimum transfer that drives out the eighteen firms is the most profitable transfer. That is, such a transfer is superior to a transfer that only drives out, say, ten firms. Given the lemma, then, it is straightforward to derive the exact transfer amount in this case. Specifically, one calculates the minimum transfer to a rival such that it is not profitable for a third firm to compete, or, denoting the minimum transfer as $\underline{\Delta}$, $\underline{\Delta} = 1 + c_L - 2c_H - (4)\sqrt{F}$. More generally, the minimum transfer to drive out m firms is $\underline{\Delta} = 1 + c_L - 2c_H - (K - m + 2)\sqrt{F}$.

However, the importance that it must be profitable to predate on at least one firm, essentially ruling out the corner solution, is emphasized with the next example.

Example 2: Unprofitable predation

Returning to our example in which the efficient firm (firm 1) had marginal cost c_L = .42 and the inefficient firms have marginal costs c_H = 0.6, recall that when there were nineteen inefficient firms in the market (K = 20), the efficient firm could transfer all of its technology to one inefficient firm, driving out the other eighteen firms. Suppose instead that there were initially only 3 inefficient firms (K = 4). Firm 1 now earns greater profits than when there were nineteen inefficient firms. As before, if it transfers the technology of .18 to one high cost firm, it again drives the market to a duopoly and earns the same as before. However, now its initial profit (K = 4) is greater than its profit after predating, and so it is no longer profitable to predate.

That is, it is possible that even when it can, the low cost firm may not want to predate on firms. However, this is not entirely surprising in our example since there is an exogenously small number of firms in the market given the technological structure: an additional seventeen high cost firms (K = 21) could enter and profitably produce. As a result, the high cost firms in the above example have a relatively high profit margin and so the amount of technology the industry leader must transfer to drive out the fourth firm is quite large and the low cost firm's profits are greater initially as well.

Interestingly then, a market that starts exogenously with *more* firms than another market can end up with *fewer* firms ex post once predation takes place. That is, as there are exogenously more firms in the market, predation is more likely to be profitable, and the example suggests that, if the number of firms was determined by an entry condition, then predation would always be profitable. However, the example shows that this would be a sufficient but not necessary condition: predation was profitable with twenty firms even though with free entry twenty one firms would have entered. To derive the sufficient condition, we begin by returning to our more general formulation. Formally, we say that a market satisfies an **entry equilibrium condition** if there are sufficiently many potential entrants ordered by their marginal costs in an increasing order,[13] and if the number of market participants K is determined by

$$\frac{1}{K+2}+\frac{\sum_{k=1}^{K+1}c_k}{K+2}-c_{K+1}\leq\sqrt{F}<\frac{1}{K+1}+\frac{\sum_{k=1}^{K}c_k}{K+1}-c_K .$$

If there are only two types of firms, the entry condition degenerates to

[13] For simplicity, we assume that efficient firms enter into the market first. Due to the integer problem and the coordination problem, this condition does not have to be satisfied, strictly speaking.

$$\frac{1}{K+2}+\frac{c_L+Kc_H}{K+2}-c_H\le\sqrt{F}<\frac{1}{K+1}+\frac{c_L+(K-1)c_H}{K+1}-c_H.$$

Thus, by focusing on the first inequality, we obtain,

$$c_L+(K-1)c_H\le(K+2)\sqrt{F}+(K+1)c_H-1.$$

Using the above, the low cost firm's original output level (a square root of its profit) satisfies

$$\sqrt{\pi_L(K)}=\frac{1}{K+1}+\frac{c_L+(K-1)c_H}{K+1}-c_L\le\frac{(K+2)\sqrt{F}}{K+1}+c_H-c_L.$$

Hence, the entry condition implies

$$\frac{(k+2)\sqrt{F}}{k+1}+c_H-c_L>\frac{(K+2)\sqrt{F}}{K+2}+c_H-c_L\ge\sqrt{\pi_L(K)},$$

which is satisfied for all $k = 1, 2, \ldots, K-1$. Thus, we have

$$\max_{k\in\{\underline{K},\ldots,K-1\}}\left(\frac{(k+2)\sqrt{F}}{k+1}+c_H-c_L\right)>\sqrt{\pi_L(K)}.$$

Hence, under the entry condition, we have the following proposition.

Proposition 2. Suppose that $c_L=c_1<c_2=c_3=\ldots=c_K=c_H$ holds. Suppose that the efficient firm can predate on m firms. Then, if the number of firm K is determined by the entry equilibrium condition, it is optimal for it to predate on all m firms. The market equilibrium has $K-m$ firms with at least one firm more efficient.

Our running example helps to emphasize two points that may not be immediate from proposition 2. First, that predation can radically change the market structure, going from a twenty firm oligopoly to a duopoly. Second, the remaining rival(s) can be more efficient than any of the original firms. Indeed, the structure may result in $\underline{K}$ firms all with the lowest cost possible. As a result, the proposition has an interesting implication for the dominant firm/competitive fringe model: the dominant firm has an incentive to transfer technology so that the market is characterized instead by a few low cost oligopolists.

We now consider the role of the commonly made assumption that there are only two types of firms. Not surprisingly, the above result is weakened. This can be seen as follows. Given that firm 1 predates on firms, its maximization problem is to choose the optimal number K^*.

$$K^* = \arg\max_{k \in \{\underline{K}, \ldots, K-1\}} \left(\frac{(k+2)\sqrt{F}}{k+1} + c_{k+1} - c_1 \right).$$

Since c_k s are now heterogeneous ($c_1 \le c_2 \le \ldots \le c_K$), we can no longer say that $\underline{K}$ is the optimal number. Nonetheless, by the same argument as before, if we impose the entry equilibrium condition and if c_K is sufficiently close to c_{K+1}, we can still get a version of Proposition 2.

Proposition 2′. Suppose that c_K is sufficiently close to c_{K+1} and that the efficient firm (firm 1) can predate on firms. Then, if the number of firm K is determined by the entry equilibrium condition, it will optimally predate on at least one highest cost firm by transferring technology to lower cost rivals.

Note that the condition of c_K being sufficiently close to c_{K+1}, together with the entry equilibrium condition, guarantees that firm 1 is better off by predating on at least firm K. However, $K^* = \underline{K}$ is not necessarily true since we have an arbitrary cost structure for the rest of the firms.

Finally, we turn to the question of the *modus operandi* of the predator. Although Proposition 2 states that the efficient firm will predate, the manner of its predations is only to choose the minimum average cost that drives out the $\underline{K}+1$ firm, that is

$$\sum_{k=1}^{\underline{K}} c_k' = (\underline{K}+2)\sqrt{F} + (\underline{K}+1)c_H - 1.$$

However, this imposes little restrictions on *how* the average cost is reduced. For example, the efficient firm could give the $\underline{K} - 1$ firms an equal amount of transfers to reduce all remaining firms costs equally or perhaps it could give just one firm a large transfer. While the choice is trivial to the predator it is not trivial with respect to welfare, as holding average marginal cost constant, increasing the variance raises welfare (Salant and Shaffer 1999). The expression also suggests that the analysis might be more general in one way. While we assumed that only the efficient firm could transfer the technology, potentially the outcome is the same if another firm, once it was transferred the technology, could then pass on the technology. After all, all remaining firms have the same objective: to maximize the ex post price.

4.2 Welfare effects of profit maximizing predation

We first examine consumer welfare by comparing the market price. Since $p(k;c) \equiv \frac{1}{k+1}+\frac{k}{k+1}\bar{c}(k)$, after the technology transfer, we have

$$p(\underline{K};c') \equiv \frac{1}{\underline{K}+1}+\frac{\sum_{k=1}^{\underline{K}} c_k'}{\underline{K}+1}$$

$$= \left(\frac{(\underline{K}+2)\sqrt{F}}{\underline{K}+1} + c_H \right)$$

Thus, since price is maximized under the constraint, $p(K;c') \geq p(K;c)$, consumers are always worse off from profitable predation.

Consider now the effect on aggregate profits. On one hand, marginal cost and fixed costs (through exit) decrease and clearly profits of the remaining firms increase. In fact, the efficient firm by predating is creating an externality for the remaining firms, including any surviving high cost ones that receive no transfers. This is somewhat analogous to the effect that mergers have on outsiders. However, in contrast to the “merger paradox” here the efficient firm benefits more than outsiders who do not receive transfers: all firms obtain the higher price, but the efficient firm has greater output. On the other hand, there is lost profit from those firms that exit, and aggregate output decreases, so the aggregate effect on profits is not immediately obvious. However, by determining the total welfare effect we will be able to comment on producer surplus.

Turning to aggregate welfare, the effect predation has is not readily apparent: consumers are made worse off and the aggregate effect on producers is unclear. Analyzing the question at a more general level does not bring an immediate answer either. On one hand, predation reduces the fixed costs of production. On the other hand, as we know from Lahiri and Ono (1988), transferring a cost reduction to another firm does not necessarily increase welfare. Further, the efficient firm only engages in such transfers when it induces exit that causes the equilibrium price to increase (and so consumers are harmed). The predator is only maximizing its profits. Despite these negative effects, we can show that the net effect of profitable predation is for welfare to increase.

Proposition 3: Suppose that $c_L = c_1 < c_2 = c_3 = ... = c_K = c_H$ holds. Profit maximizing predation always increases welfare, although consumer surplus is always reduced by predation. Thus, the aggregated profit of the industry goes up, though some firms go out of business.

The policy implication is that predation via cost savings should be permitted. So, while we have found a reason for why rivals should be nervous about joint production (as with GM and Toyota) and for consumers to be harmed, net efficiency increases with predation.

Although the proof is given in the appendix, we note that in it we assume that the predator chooses the least efficient (in welfare terms) way to lower average marginal cost (Salant and Shaffer 1999). That is, we assume that the predator lowers its $K-1$ rivals by an equal amount.[14] Obviously, if the predator chooses any other type of technology transfer predation then the welfare gain is even greater. For example, if instead it gives the cost reduction to only one rival, this would result in a

[14] In our model, the efficient firm is indifferent among the ways to transfer technology as long as it can predate on the same number of firms.

greater welfare increase from the predation.

We close this section by noting that the proof of proposition 3 does not depend on the entry condition. While there is an efficiency gain from the fixed cost savings, in the hypothetical case of no fixed costs ($F = 0$), the welfare result could still hold, although then predation could not occur. In such a case, the welfare result turns on the fact that inefficient firms steal production from the more efficient firm and so by driving them from the market welfare increases and of course the efficiency gain from the inefficient firms being made more efficient (Lahiri and Ono 1988). However, as proposition 2 demonstrates, the latter need not necessarily be positive.

4.3 Predation with entry: the entry equilibrium *K* reconsidered

When characterizing the entry equilibrium K for the sufficient condition, the possibility for predation was not accounted for; in essence, the equilibrium K is for an industry in which predation will not occur. We then asked if predation were allowed (say by policy makers), what would be the effects. However, if entrants enter realizing that predation is permissible, then the original equilibrium could well be affected. While it is natural to think that the result would be in less entry, it is quite possible that instead more entry would result from policy makers allowing for predation! Intuitively, the predation benefits both the efficient firm and those that receive the transfer. With the entry condition, the loss profits from those that exit are relatively small. To show this possibility, we will ignore the integer constraint in considering the entry equilibrium so that the marginal entrant's profit (and hence all high cost firm's profits are zero).

To be more precise, assume now that to enter a high cost firm must now incur an entry cost E (sunk cost). Then, as before, the efficient firm chooses its profit maximizing amount of technology transfer as above. After the transfers the firms choose whether to exit, and the remaining firms exit.

As a benchmark, consider what occurs if the efficient firm is not allowed to predate. Potential entrants anticipate that if K firms enter then the resulting price will be $p(K)$. In the first stage, then, firms will enter until

$$(p(K) - c_H)^2 - F - E = 0$$

Denote K' as the K defined by the above equation.

Consider now what occurs if the efficient firm is allowed to predate. The firms anticipate that the price after predation will be $p(\underline{K};c') > p(K')$ and that there will only be $\underline{K} < K'$ firms remaining. In addition, if it remains its cost may decrease through the transfer. Thus, with K' entrants, the expected profits for an entrant is, at a minimum,

$$\underline{K}[(p(\underline{K};c') - c_H)^2 - F]/K' - E$$

Thus, if entry cost is sufficiently small ($E \to 0$), then the predation will lead to more entry since $(p(K') - c_H)^2 - F$ approaches zero and $(p(\underline{K};c') - c_H)^2 - F > (p(K') - c_H)^2 - F$. Thus, the expectation of predatory behavior could lead to more entry in the initial stage. This outcome is reminiscent of firms entering a market in hopes of being bought out by the incumbent (Rasmusen 1988, Ordover and Saloner 1989).

5. Conclusion

In this paper we considered the impact of joint production (essentially, technology transfers with the firms remaining independent) on a firm's profits when monetary transfers are not allowed. Essentially, we are asking: why would Toyota have enabled its largest rival (GM) to make huge productivity gains? We find that if the number of firms in the market is variable, then a unilateral transfer of a firm's technology to a higher-cost rival with no *quid pro quo* can be profitable. The reason is that such technology transfer works as a credible threat of predatory behavior, resulting in a smaller number of firms and a higher price in the market.

We then focus on this predation "by proxy" in more detail by allowing *partial* technology transfers to *multiple* firms. We find that when there are one low cost firm and multiple high cost firms, then it is profit maximizing for the low cost firm to predate on *every* firm that it can when it wants to predate on at least one firm. Furthermore, predation is actually *always* profitable when high cost firms can enter into the market freely. As a result of the predation the market price increases. Although this price increase reduces consumer surplus, social welfare (and thus, industry profit) increases from the profit-maximizing amount of predatory technology transfers.

Finally, while our focus has been on predation, as with most predation models, our analysis can also be applied to entry deterrence. For example, it could be argued that even in the early 1980s entry into the US auto market was restricted but that this restriction was ebbing away. Toyota may well have been concerned with new manufactures (e.g., Korean manufacturers) and attempted expansion (or re-entry) by others. In such a case, technology transfers to inefficient rivals could be profitable if it worked to deter entry into the US market for the same reason predation could be profitable. Finally, if this were Toyota's plan *ex ante*, Toyota may not have realized how long it would have taken GM *ex post* to be able to reduce its costs.

Appendix: Proofs of Lemma 1, and Proposition 3

Lemma 1. Assume interior solutions. Then, for all $K = 2,3\ldots$, we have

1. $\pi_k(K) \geq \pi_{k+1}(K)$ for all $k \in \{1, \ldots, K-1\}$

2. $Q(K-1) < Q(K)$

3. $p(K-1) > p(K)$

4. $q_k(K-1) > q_k(K)$ for all $k \in \{1, \ldots, K-1\}$

5. $\pi_{K-1}(K-1) > \pi_K(K)$.

Proof. Since it is trivial to see that 1 holds, we will show that 2 holds.

$$Q(K) - Q(K-1) =$$

$$= \frac{1}{K(K+1)} - \frac{\sum_{k'=1}^{K} c_{k'}}{K+1} + \frac{\sum_{k'=1}^{K-1} c_{k'}}{K}$$

$$= \frac{1}{K(K+1)} + \frac{\sum_{k'=1}^{K} c_{k'}}{K+1} - \frac{c_K}{K}$$

$$= \frac{1}{K}\left[\frac{1}{K+1} + \frac{K}{K+1}\bar{c}(K) - c_K\right] > 0.$$

The inequality holds by our interior solution requirement $q_K(K) > 0$. Given this, 3 and 4 are straightforward. (5 can be shown by 1, 3 and 4.).//

Proposition 3: Suppose that $c_L = c_1 < c_2 = c_3 = \ldots = c_K = c_H$ holds. The profit maximizing predation always increases welfare, although consumer surplus is always reduced by predation.

Proof: We already know that market price increases by predation. Thus, consumer surplus definitely decreases. We will concentrate on social welfare in the rest of the proof. It is straightforward to verify that since $P(\hat{K};c^{'}) > P(K)$ the change in social welfare from the predation is

$$\Delta SW = \frac{1}{2}(P(\hat{K};c^{'}) - P(K)) \times \Delta(\text{output}) + P(K) \times \Delta(\text{output}) - \Delta\left(\text{total cost}\right)$$

Now, since

$$P(\hat{K};c^{'}) = \left(\frac{(\hat{K}+2)\sqrt{F}}{\hat{K}+1} + c_2\right),$$

and since K firms are present in the original equilibrium,

$$P(K) \geq \left(\sqrt{F} + c_2\right),$$

the first two terms can be written as

$$\frac{(P(\hat{K};c^{'}) - P(K))}{2} \times \Delta(\text{output}) + P(K) \times \Delta(\text{output}) = \frac{1}{2}(P(\hat{K};c^{'}) + P(K)) \times \Delta(\text{output})$$

$$\geq \frac{1}{2}\left[\left(\frac{(\hat{K}+2)\sqrt{F}}{\hat{K}+1} + c_2\right) + \left(\sqrt{F} + c_2\right)\right] \times \Delta(\text{output})$$

$$= \left[\frac{1}{2}\left(\frac{\sqrt{F}}{\hat{K}+1}\right) + \left(\sqrt{F} + c_2\right)\right] \times \Delta(\text{output})$$

$$= \left[\frac{1}{2}\left(\frac{\sqrt{F}}{\hat{K}+1}\right) + \sqrt{F}\right] \times \Delta(\text{output}) + c_2 \times \Delta(\text{output})$$

$$\geq -\left[\frac{F}{2\left(\hat{K}+1\right)^2} + \frac{F}{\hat{K}+1}\right] + c_2 \times \Delta(\text{output})$$

The first inequality follows from the entry equilibrium condition and the last inequality holds since

$0 > \Delta(\text{ output}) \geq -\frac{\sqrt{F}}{\hat{K}+1}$, since $\Delta(output) = P(\hat{K}) - P(K) \geq \frac{(\hat{K}+2)\sqrt{F}}{\hat{K}+1} + c_2 - \sqrt{F} - c_2$.

Now, let us investigate total cost reduction. The original total cost is written as,

$$C = c_1 q_1 + (K-1)c_2 q_2 + K \cdot F.$$

The new total cost is

$$\hat{C} = c_1 \hat{q}_1 + \sum_{k=2}^{\hat{K}} c_k^{'} \hat{q}_k + \hat{K}F.$$

Hence, the change in social welfare is

$$\Delta SW = \frac{1}{2}(P(\hat{K}; c^{'}) - P(K)) \times \Delta(\text{output}) + P(K) \times \Delta(\text{output}) - \Delta\left(\text{total cost}\right)$$

$$\geq -\left[\frac{F}{2(\hat{K}+1)^2} + \frac{F}{\hat{K}+1}\right] + c_2 \times \Delta(output) - \left(\hat{C} - C\right)$$

$$= -\left[\frac{F}{2\left(\hat{K}+1\right)^2} + \frac{F}{\hat{K}+1}\right] + c_2 \times \left[\hat{q}_1 + \sum_{k=2}^{\hat{K}} \hat{q}_k - q_1 - (K-1)q_2\right]$$

$$+ \left[\left(c_1 q_1 + (K^* - 1)c_2 q_2\right) - \left(c_1 \hat{q}_1 + \sum_{k=2}^{\hat{K}} c_k^{'} \hat{q}_k\right)\right] + \left(K - \hat{K}\right)F$$

$$\geq -\left[\frac{F}{2\left(\hat{K}+1\right)^2} + \frac{F}{\hat{K}+1}\right] + c_2 \times \left[\hat{q}_1 + \sum_{k=2}^{\hat{K}} \hat{q}_k - q_1 - (K-1)q_2\right]$$

$$+ \left[\left(c_1 q_1 + (K^* - 1)c_2 q_2\right) - \left(c_1 \hat{q}_1 + (\hat{K} - 1)c_2 \sum_{k=2}^{\hat{K}} \hat{q}_k\right)\right] + \left(K - \hat{K}\right)F$$

$$= \left[\left(K - \hat{K}\right) - \frac{1}{2\left(\hat{K}+1\right)^2} - \frac{1}{\hat{K}+1}\right] \times F + (c_2 - c_1)\left(\hat{q}_1 - q_1\right),$$

where the second inequality holds since $c_1 \leq c_2^{'} < c_2$. Thus, in order to show $\Delta W > 0$, it is sufficient to show $\hat{q}_1 \geq q_1$. Since $q_k = P(K) - c_k$ for each k and $P(K) < P(\hat{K})$, $\hat{q}_1 > q_1$ indeed holds. Hence, the social welfare improves.//

References

Bloch, F., 1995, "Endogenous Structures of Association in Oligopolies," *The RAND Journal of Economics*, 26(3), pp. 537-556.

Boldrin, M. and D.K. Levine, 2004, "The Case Against Intellectual Monopoly," *International Economic Review* 45, 327–50.

Bolton, P., J. Brodley and M. Riordan, 2000, "Predatory pricing: Strategic theory and legal policy", Georgetown Law Journal 88:2239-2330.

Bolton, P. and D.S. Scharfstein, 1990, "A Theory of Predation baaed on Agency Problems in Financial Contracting, *American Economic Review*, 80(1), 93-106.

Caves, R. E., H. Crookell, J.P. Killing, 1983, The imperfect market for technology licenses, *Oxford Bulletin of Economics and Statistics*, 45, 249-67.

Chen Z.Q, and T.W. Ross, 2000, Strategic alliances, shared facilities, and entry deterrence, *RAND Journal of Economics* 31 (2): 326-344 Summer.

Creane, A. and H. Konishi, 2007, Technology Transfers and Joint Profits with Heterogeneous Technologies, working paper.

Cullison, A.E., 1989, Kobe Steel Plans Joint Production with USX, *Journal of Commerce*, February 15, 1989, p. 1A.

DeTar, J., 2000, Toshiba, SanDisk: Thanks For The Memories, *Investor's Business Daily*, May 10, p. A6.

Farrell, J. and C. Shapiro, 1990a, "Horizontal Mergers: An Equilibrium Analysis," *American Economic Review*, 80(1), pp. 107-126.

Farrell, J. and C. Shapiro, 1990b, "Asset Ownership and Market Structure in Oligopoly," *RAND Journal of Economics*, 21(2), pp. 275-292.

Fenton, K.M., 2005, "GM/Toyota: Twenty Years Later," *Antitrust Law Journal*, 72, 1013-1028.

Genesove, D. and W. Mullin, 1997, "Predation and Its Rate of Return: The Sugar Industry, 1887–1914," *NBER Working paper*.

Genesove, D. and W. Mullin, 2006, "Predation and Its Rate of Return: The Sugar Industry, 1887–1914," *RAND Journal of Economics*, 37(1), 47-69.

Kamien, M.I. and Y. Tauman, 1986, "Fees versus royalties and the private value of a patent," *Quarterly Journal of Economics*, 101, 471-492.

Kamien, M. and Zang, I., 1990, "The Limits of Monopolization through Acquisition," *Quarterly Journal of Economics,* 105(2): 465-499.

Kaplow, L. and C. Shapiro, 2007, "Antitrust," *in* Handbook of Antitrust, A.M. Polinsky and S. Shavell, eds., Elsevier: New York.

Lahiri, S. and Y. Ono, 1988, "Helping Minor Firms Reduces Welfare," *The Economic Journal*, 98(393), pp. 1199-1202.

Merx, K., 2007, "Good news for GM in its battle with Toyota," *Detroit Free Press*, in Business and Financial News, 1 June.

Ordover, J.A. and G. Saloner, 1989, "Predation, Monopolization and Antitrust," *in* Handbook of Industrial Organization, 1, R. Shmalensee and RD. Willig, eds., Elsevier: New York.

Porter, M., 1990, "Don't Collaborate, Compete," *Economist*, June 9, p. 17.

Rasmusen, E., 1988, "Entry for Buyout," *The Journal of Industrial Economics*, 36(3), pp. 281-299.

Salant, S. and G. Shaffer, 1999, "Unequal Treatment of Identical Agents in Cournot Equilibrium," *American Economic Review*, 89(3), 585-604.

Salant, S., S. Switzer, and R. Reynolds, 1983 "Losses Due to Merger: The Effects of an Exogenous Change in Industry Structure on Cournot-Nash Equilibrium," *Quarterly Journal of Economics,* 48, 185-200.

Salop, S.C. and D.T. Scheffman, 1983, "Raising rivals' costs," *American Economic Review*, 73, 267-271.

Shapiro, C., and R. D. Willig, 1990, On the Antitrust Treatment of Production Joint Ventures, *The Journal of Economic Perspectives*, 4(3), pp. 113-130.

Teece, D.J., 1976, The multinational corporation and the resource cost of international technology transfer. (Ballinger, Cambridge, MA).

Teresko, J., 2006, "Learning From Toyota – Again," *Industry Week*, 1 February.

Smith, C., 2001, "Kagome links with Heinz in Japan," *Daily Deal*, July 26.