The Unilateral Incentives for Technology Transfers:

Predation (and Deterrence) by Proxy [§]

Anthony Creane[†] and Hideo Konishi[‡,]

Joint production between rival firms often entails knowledge transfers without direct compensation, leaving the question as to why more efficient firms would give their rivals such an advantage. We find that such transfers are credible mechanisms to make the market more competitive so as to deter entry or force exit. We determine that with free entry such transfers are profitable and further it may be optimal to predate or deter <u>every</u> firm possible so that a market with many firms can become a duopoly. While consumers are harmed by such action, production efficiency normally increases sufficiently to cause welfare to increase.

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

[†]Michigan State University
[‡]Boston College

1. Introduction

In 1984 General Motors and Toyota began the controversial joint production of vehicles at the New United Motors Manufacturing Inc. (NUMMI) in Fremont, California.[1] The FTC had narrowly approved the venture (3 to 2), partly defending the approval on the basis of GM being able to produce cars more cheaply this way and on GM getting the chance to learn and use "Toyota's efficient manufacturing and management methods" (Fenton 2005). The FTC decision is today viewed as a watershed, reflecting a major policy reassessment of such agreements as well as mergers. Since then joint production agreements involving technology transfers have occurred or been proposed in other industries including the steel industry (e.g., USX and Kobe Steel, Cullison 1989) and food packaging (Heinz and Kagome, Smith 2001), especially since the passage of the National Cooperative Production Amendments in 1993.

The reassessment of joint production agreements and mergers was partly shaped by findings of contemporaneous research. While previously the concern was that such agreements could have welfare-worsening collusive effects, Salant et al. (1983) showed that once the non-merged firms' strategic reactions are accounted for, such agreements are less likely to be profitable for collusive reasons, and even if they are, then they are unlikely to be stable (Kamien and Zang 1990). Thus, the supposition is that efficiency reasons are often the motivation for such agreements.

Yet, in the above examples the firm transferring the technology would not directly benefit from efficiency effects of the agreements as there were no "licensing" fees charged to the firm receiving the superior firm's know-how or technology. Indeed, there can be significant costs for such arrangements.[2] For example, Toyota had considerable legal and time expenses shepherding the

---

[1] For greater details on the controversy see the discussion in our working paper Creane and Konishi (2007).
[2] 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.

agreement through the US regulators as well as the FTC's constraints on the agreement including both production limits and a time limit of twelve years on the venture (and a lawsuit from Chrysler), none of which Honda or Nissan faced with their independent plants that began *before* NUMMI. As noted by the Washington Post (1984) "the plan raises questions about why the joint-venture approach was taken if GM could have imported cars anyway and Toyota could have built cars here."[3,4] To this we add the question as to why would one firm would give a rival the ability to become more efficient without receiving compensation.

In this paper we explore these questions. Our main finding is that by extending the standard analysis and allowing for free entry (or exit) into the market, there can be a profitable, strategic advantage from such agreements: by making a rival more efficient the firm can deter future entry (or predate on other rivals). In this sense, our work can be viewed as being in line with the literature on credible deterrence or predation (e.g., Rockett 1990). This benefit obviously is independent of whether the superior firm receives a payment in addition, though for this reason, our paper also is related to the licensing literature which examines when technology transfers are *jointly* profitable (e.g., Katz and Shapiro 1985 and Kamien and Tauman 1986) while we examine if such transfers are *unilaterally* profitable. Our work can also be interpreted as examining the benefits from licensing when there is entry or exit and in this sense our work can be viewed as being in line with recent work that has revisited earlier results in the context of entry and exit (Etro 2006 and Davidson and

---

[3] See also Weiss, et al. (1996) regarding the FTC concerns with Toyota executives' candidness as well as their reticence when testifying.

[4] There have been other arguments made for why Toyota was involved including (i) gain experience with American unionized labor, (ii) gain experience with American suppliers, and (iii) help diffuse the trade issue between the United States and Japan (see, e.g., Duerer et al. 2005). Clearly (iii) does not answer why Toyota did not choose an independent plant. With respect to the first two points, Toyota already had a unionized parts plant in California since 1972 (TABC, Inc). Second, both Honda and Nissan had already had independent, non-union plants in the United States before NUMMI. Third, Toyota had other foreign plants including unionized plants in Australia, Ireland and Portugal dating back to the 1970s. However, Toyota never had a joint venture with a rival vehicle manufacturer. Fourth, Toyota shortly thereafter began a non-unionized plant in the United States (as were all of their subsequent plants). Fifth, as noted above, the joint production with GM had considerable delay and legal costs as well as restrictions imposed by the FTC. Similar arguments could be made for other joint productions as well.

Mukerjee 2008).

To be more specific, a less efficient firm's technological gains from joint production will, holding the number of firms constant, lower the equilibrium price, which harms the firm making the transfer – what we call the "cost effect." However, when entry or exit is possible, such transfers could prevent entry or drive out rival firms, which would be a benefit to the firm making the transfer, which we call the "predation effect." Despite the harm from having a more efficient rival, we find that the predation effect can dominate: it can be profitable for firm to predate "by proxy" through joint production. Thus, joint production could indeed have anti-competitive effects – confirming the misgivings of many regarding such alliances – but in the form of reducing the equilibrium number of firms rather than from direct collusion. More broadly, even if this is not the only reason for the technology transfers, this predation effect can on the margin cause the size of the technology transfer to increase.

In our analysis we consider which partner among its rivals the technologically superior firm – for ease called the predator – would choose. An immediate result is that the least efficient firm or entrant is never the partner (unlike in Rockett 1990), as this firm is the most vulnerable. Second, there is a trade-off facing the predator: it wants its partner's cost reduction to be large enough to affect entry or exit, but not so large that the predator is harmed by the more efficient rival it has created. Despite these conflicting requirements, deterrence or predation by proxy can occur and result in a significant change in the market structure: for example, from many rivals to a duopoly.

To give a context to these trade-offs, we then adopt the standard framework of the licensing literature (e.g., Katz and Shapiro 1985 and Kamien and Tauman 1986). As noted above, the questions examined in the licensing literature and in our model are similar except that we do not allow the firm with the superior technology to receive any payment. Hence it is natural to consider their basic framework: a firm with a superior technology facing rivals that use a lesser one. This is also the framework of the classic dominant firm model. We show that when there is free entry of the

less efficient firms in this setting, the unilateral transfer of technology is always profitable (proposition 2). 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 (lemma 4) even 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. 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 deterrence or 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, which is an implication of Bergstrom and Varian (1985).

We then characterize the welfare effects of predation by proxy in the more general setting. On one hand, deterrence or predation only occurs if it is profitable to the predator. In addition it creates a positive externality for those firms that receive the transfers. On the other hand, 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 (nor welfare). 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 concern that such agreements harm consumer welfare. Finally, as Lahiri and Ono (1988) show, making an inefficient firm more efficient can be welfare reducing. Despite these negative effects we find that normally the gains in production efficiency from profitable predation by proxy will always offset the other losses, 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. Furthermore, proposition 3 suggests paradoxically that technology transfers to inefficient firms are less likely to reduce welfare when it is likely to deter entry or induce exit.

In the next section we present an overview of the literatures and how our results are related to previous work. The subsequent section presents the basic assumptions. In section 4, we derive conditions for joint production pairings to be profitable for the more efficient firm when it receives no direct cost benefit because of its ability to deter entry or drive out other rivals. In section 5, we analyze the incentives for an industry leader to be a predator on its rivals, section 6 considers the welfare implications of predation by proxy and section 7 concludes.

2. Literature Review

As noted in the introduction, our model is related to three different literatures. First, there is a rich literature on credible entry deterrence or predation. The recent literature perhaps started with Dixit's (1980) seminal work on how investment could deter entry. The closest work to ours is Rockett's (1990) examination of an incumbent monopolist who faces two potential entrants. Rockett (1990) shows that, under certain conditions, the incumbent will license its technology to the less efficient potential entrant to block the more efficient entrant from entering. In addition to differing results (the less efficient entrant never receives the technology in our environment), a notable difference is that in our model the predator does not receive a payment from the firm that obtains its technology. Even closer is the work by Chen and Ross (2000), who examine how joint production can be offered by a monopoly incumbent to a potential entrant to prevent full scale entry by the entrant.[5] The primary difference with our work is that we have more than one potential entrant or rival.

Rockett's work (1990) is also obviously related to the licensing literature, which examines, more generally, the conditions for it to be profitable for an efficient firm to license its superior technology to a less efficient firm. The more recent literature started with Katz and Shapiro (1985) and Kamien and Tauman (1986) and for an overview of the literature, see Sen and Tauman's (2007)

---

[5] Other aspects of joint production have been examined in 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.

examination of the welfare effects from licensing. Clearly it is more difficult in our model for "licensing" to be profitable since the "licensor" receives no payment. Thus, our result can be thought of as a sufficient condition for licensing to be profitable.

Finally our analysis is also in line with recent work which has re-evaluated standard results in light of entry or exit decisions (e.g., Etro 2006 and Davidson and Mukerjee 2008). Davidson and Mukerjee (2008) show that with only small cost gains mergers can be profitable once free entry is allowed contrary to models that do not allow entry. Etro (2006) shows in a general setting that, contrary to when there is an exogenous number of firms, with entry, a first mover always chooses the "top dog" strategy because of its affect on entry. In contrast, in our model the firm does not invest to make itself tough, but rather one (or more) of its rivals.

3. The Model

As we are examining joint production, the basic Cournot market structure is a natural starting point. We consider a general demand function with strategic substitutability. There is a commodity besides a numeraire good, and its demand curve is described by a twice continuously differentiable monotonically decreasing function for $Q \leq \bar{Q}$:

$$p = p(Q)$$

where $p(0) = 1$, $p(Q) \geq 0$ if $Q \leq \bar{Q}$, and $p(Q) = 0$ otherwise. Thus, $p'(Q) < 0$ for all $Q \in (0, \bar{Q})$. We begin by assuming that 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 (or not enter into) the market. 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:

$$\pi^k(q_k, q_{-k}) = \left(p(Q) - c_k \right) q_k - F$$

$$= \left(p\left(\sum_{k'=1}^{K} q_{k'} \right) - c_k \right) q_k - F,$$

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

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

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

$$p'(Q)Q + Kp(Q) - \sum_{k'=1}^{K} c_k = 0. \tag{1}$$

Let

$$\phi(Q, K) = p'(Q)Q + Kp(Q).$$

Then, we have

$$\phi_Q(Q, K) = p''(Q)Q + (K+1)p'(Q) < 0,$$

since strategic substitutability means

$$p''(Q)q_k + p'(Q) \leq 0$$

for all $k=1,...,K$. Thus, as $C = \sum_{k'=1}^{K} c_{k'}$ increases, and as K decreases, the aggregated quantity $Q^e(C,K)$ that satisfies (1),

$$\phi(Q, K) - C = 0$$

decreases monotonically: $\partial Q^e / \partial C < 0$ and $Q^e(C, K-1) < Q^e(C, K)$. To summarize:

Lemma 1. The solution of equation (1), $Q^e(C,K)$, satisfies $\partial Q^e / \partial C < 0$ and $Q^e(C, K-1) < Q^e(C, K)$.

Noting that $Q^e(C,K)$ is the equilibrium output of this problem, we have the following.

Lemma 2. For all marginal cost profile $\mathbf{c} = (c_1,...,c_K)$, there exists unique equilibrium, which is characterized by $p^e = p(Q^e)$, $q_k^e = q_k(Q^e) = \left.\dfrac{p(Q)-c_k}{-p'(Q)}\right|_{Q=Q^e}$, $\pi_k^e = \pi_k(Q^e) = \left.\dfrac{(p(Q)-c_k)^2}{-p'(Q)}\right|_{Q=Q^e} - F$, where Q^e is a solution of (1). Thus, we have

1. $\pi_1^e \geq \pi_2^e \geq ... \geq \pi_K^e$,

2. $q_1^e \geq q_2^e \geq ... \geq q_K^e$,

3. $q_k'(Q) < 0$ and $\pi_k'(Q) < 0$.

4. Joint Production as Profitable Predation

We begin our analysis by examining which rival firm would a more efficient firm – for ease referred to as the 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. Indeed, previous to its agreement with GM, Toyota had been in discussion with Ford. Other examples include Kobe Steel which chose USX, and Kagome which choose Heinz, to share their knowledge through joint production.[6] 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.

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, 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

---

[6] 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.

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 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.[7]

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 $\Delta_k \leq \Delta_{k'}$, i.e., the marginal cost of firm k' becomes $c_{k'} - \Delta_{k'}$. Since we are interested in joint production as a purely predatory or deterrent device, we will assume that the more efficient firm receives no cost reduction, i.e., $\Delta_k = 0$. It is easy to see intuitively 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.

To derive this explicitly we begin by noting that from Lemma 1

$$Q^J = Q^e(C - \Delta_k - \Delta_{k'}, K) > Q^e(C, K) = Q^e,$$

where the superscript J indicates Joint production. Assuming that the number of firms does not change, the equilibrium looks as follows:

$$p^J = p(Q^J) < p^e$$

$$\pi_k^J = \frac{\left(p(Q^J) - c_k + \Delta_k\right)^2}{-p'(Q^J)} - F$$

$$\pi_{k'}^J = \frac{\left(p(Q^J) - c_{k'} + \Delta_{k'}\right)^2}{-p'(Q^J)} - F$$

Since a joint production is a voluntary agreement between the two firms, if a joint production takes

---

place, $\pi_k^J > \pi_k^e$ and $\pi_{k'}^J > \pi_{k'}^e$ must hold. Thus, the condition for this to happen is

$$\frac{\left(p(Q^J) - c_k + \Delta_k\right)^2}{-p'(Q^J)} > \frac{\left(p(Q^*) - c_k\right)^2}{-p'(Q^*)}$$

and

$$\frac{\left(p(Q^J) - c_{k'} + \Delta_{k'}\right)^2}{-p'(Q^J)} > \frac{\left(p(Q^*) - c_{k'}\right)^2}{-p'(Q^*)}.$$

If $\Delta_k = 0$, then firm k gains from a joint production if profit gross of fixed costs,

$$\psi_k(Q) = \frac{\left(p(Q) - c_k\right)^2}{-p'(Q)},$$

is increasing in Q on the interval (Q^e, Q^J), which we show formally to be not true in the appendix. As a result, we have

Lemma 3. When $\Delta_k = 0$, firm k does not engage in a joint production if it does not reduce the number of active firms.

This simply is the cost effect of a technology transfer: a firm never benefits from making its rival more efficient so long as the number of rivals is exogenous. From now on, we will focus on pure technology transfer case throughout the paper: i.e., we will assume that joint production simply closes the cost gap between the two firms without changing more efficient firm's marginal cost.

Once we allow for the possibility of exit, the market price could, instead, increase as a result of the exit induced by the cost reducing joint production. Thus, we assume a two stage game *after joint production decision has been made*: in stage 1, firms choose whether to stay in the industry or not, and in stage 2, the firms that stayed in the industry play a Cournot game.[8]

As is shown above, joint production effectively lowers the marginal cost of firm k', and

---

[8] To modify this for the deterrence game, in stage 1 firms choose whether to enter the market and K would be the equilibrium number of firms that enter if no joint production occurs *beforehand*. The joint production decision could be made with firms that are planning to enter the market.

aggregate output increases $Q^J > Q^e$ and so the price decreases. Other than firm k', all of the other firms' net profits decrease, and some firms may have negative net profits if the number of firms (K) is unchanged. Let us focus on the highest cost firm, which for clarity we will denote K (for notational simplicity, assume $k' \neq K$). Since price decreases with joint production, firm K exits if its resulting profits are negative. However, without the joint production firm K must have been viable, that is, its profits were positive. Thus, for predation to be feasible on firm K, its cost must satisfy

$$\psi_K(Q^J(K)) = \frac{\left(p(Q^J(K)) - c_K\right)^2}{-p'(Q^J(K))} \leq F < \frac{\left(p(Q^e) - c_K\right)^2}{-p'(Q^e)} = \psi_K(Q^e). \tag{2}$$

In addition to being feasible, for predation to occur, it must be profitable for the predator. Note that, after firm K exits, firm k's ($k \neq K$) profit must increase. Further, since $\pi_k = \pi_k(Q) = -(p(Q) - c_k)^2/p'(Q) - F$, if equilibrium output (Q) with firm K's exit and the technology transfer is less than the equilibrium output without the transfer (and firm K remaining), then profit of firm k is greater with the technology transfer. That is, we need $Q^J(K-1) < Q^e$ for predation to be profitable, where $Q^J(K-1)$ is a solution of

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

and Q^e is the solution of

$$p'(Q)Q + Kp(Q) - \sum_{k'=1}^{K} c_k = 0.$$

Since both $p'(Q)Q + (K-1)p(Q)$ and $p'(Q)Q + Kp(Q)$ are decreasing in Q, we can show $Q^J(K-1) < Q^e$ if

$$p'(Q^e)Q^e + (K-1)p(Q^e) - \sum_{k'=1}^{K-1} c_k + \Delta_{k'} < 0.$$

Since

$$p'(Q^e)Q^e + Kp(Q^e) - \sum_{k'=1}^{K} c_k = 0,$$

the above inequality is equivalent to

$$c_K + \Delta_{k'} < p(Q^e).$$ (3)

That is, when the above inequality holds, the predation effect is greater than the cost effect: predation is profitable. Thus, we have the following:

Proposition 1.[9] A cost-reducing technology transfer from firm k to firm k' forces firm K out of the market, and the market price increases as a result, if (2) and (3) hold, that is

$$\frac{\left(p(Q^J(K)) - c_K\right)^2}{-p'(Q^J(K))} \leq F < \frac{\left(p(Q^e) - c_K\right)^2}{-p'(Q^e)}$$

and

$$\Delta_{k'} < p(Q^e) - c_K.$$

To provide some insight to our conditions, we note that nested within our model is the environment in the licensing literature: there is a single firm with superior technology that chooses whether to completely share its superior technology in its entirety with a rival. (The difference between our analysis and that in the licensing literature is that in our analysis the firm making the transfer does not receive any direct payment.) For the model here that implies $\Delta_{k'} = c_{k'} - c_k$. In this environment, *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.[10] In fact, the predator would want to pick the firm most like itself as possible because (3) in this licensing setting becomes

$$c_k - c_{k'} < p(Q^e) - c_K.$$

---

[9] To modify the proposition for deterrence: A cost-reducing technology transfer from firm k to firm k' prevents firm K from entering the market, and the market price remains higher as a result, if (2) and (3) hold.

[10] We show in Creane and Konishi (2008) 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.

It is also clear then that the two conditions are somewhat contradictory. Condition (2) 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 (3) 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 it is not the empty set and to show that the results can be easily re-interpreted as one of entry deterrence.

Example 1: Unilateral technology transfer that profitably predates on high cost firms

The market is currently composed of a low cost firm and nineteen high cost firms. Let the low cost firm have marginal cost $c_L = .42$, its rival has marginal costs $c_H = .6$ and demand be linear: $p(Q) = 1 - Q$. In addition, let fixed cost of operations be $F = 1 \times 10^{-4}$ for all firms. If the low cost firm engages in joint production with one of its high cost rivals (k') so that $\Delta_{k'} = c_H - c_L$, then all other high cost firms exit resulting in a duopoly market with a higher profit for the low cost firm. 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 prevent additional firms from entering, but the efficient firm's profits would be greater without the transfer.

This example can be easily modified for entry deterrence case: The market is currently a duopoly with a low cost firm with a superior technology and a single high cost rival. In the next period, however, some barrier will be removed (e.g., trade barrier) so that entry could occur. There are a large number of firms that could enter in the next period with the high cost technology. If no technology transfer occurs, then nineteen additional high cost firms enter the market. If instead the low cost incumbent engages in joint production with its high cost rival (k') so that $\Delta_{k'} = c_H - c_L$, then no additional firms enter the market and the low cost firm's profits are greater when $c_L = 0.42$. If $c_L = 0.41$, the low cost firm would achieve a higher profit by accommodating entry.

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

5. Predation by the industry leader

In Example 1, we saw that a more efficient firm may be able to profitably predate on (or deter) a large number of firms from entering by sharing its technology with a single rival. However, the example also raises several questions about when this 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.

A second question is, even if *some* predation (or deterrence) 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 predate on eighteen firms, but would it want to, or would it only want to predate on a few firms? 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 potential rivals affects the level of predation. For example, if there are fewer firms in the market originally, then is it more likely that the predation will result a duopoly as this requires fewer firms to be preyed upon? 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?

Given our structure these questions can be answered under countless environments: there are many possible joint production pairings and a firm could choose multiple partners. To give context

---

[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.

to the answers we will apply the standard structure assumed in the licensing literature, which as we noted in the introduction asks a similar question but with payments for the technology transfer. Specifically, there is a technologically superior firm facing less efficient rivals. That is, there is an efficient firm that faces $K - 1$ less efficient firms ($c_1 \equiv c_L < c_2 = c_3 = \ldots = c_K \equiv c_H$). In addition, as before we assume that for any $k > 1$, firm k's technology is worthless for firm 1 ($\Delta_1 = 0$).

Firm 1's objective is to maximize its profits. Since any firm's profits gross of fixed costs, $\Psi_k(Q) = (p(Q) - c_k)^2 / p'(Q)$, is decreasing in aggregate output (see the proof of lemma 3 in the appendix), $\psi'_k(Q) < 0$ for all k, if equilibrium Q is smaller, firm 1 is better off. Recall that summing the first order conditions (1), we had $\phi(Q,K) - C(K) = 0$, where $C(K) = \sum_{k=1}^{K} c_i$ and $\phi(Q,K)$ $= p'(Q)Q + Kp(Q)$ with $\phi_Q < 0$. Thus, firm 1 prefers fewer rivals (smaller K) with higher costs (larger C) as these reduce equilibrium output.

A higher cost rival can be driven out if firm 1 can increase aggregate output (Q) to the point where it is no longer profitable for that firm to operate. Thus, let $\hat{Q}$ be the output such that

$$\psi_k(\hat{Q}) = \frac{\left(p(\hat{Q})) - c_H\right)^2}{-p'(\hat{Q})} = F.$$

Since $\psi'_k(Q) < 0$, such $\hat{Q}$ is uniquely determined. If the aggregate output level reaches at $\hat{Q}$, high cost firms are indifferent between exiting or staying in business and by our tie-breaking rule, one of the high cost firms exit.

Firm 1 can increase aggregate output (thereby driving out a firm) by making a technology transfer that reduces C sufficiently. That is, it can determine K by its choice of C. This relationship between C and K facing firm 1 is defined by $\hat{Q}$, the output that would drive out a high cost firm. From (1), the equilibrium aggregated output is determined by

$$\phi(Q, K) - C = p'(Q)Q + Kp(Q) - C = 0. \tag{4}$$

Thus, for each K we can calculate the C that achieves $\hat{Q}$ if it exists. Denote such a C for each K by $C^*(K)$. We can then establish a relationship between K and $K + 1$ in terms of C by using the equilibrium output condition (4):

$$p'(\hat{Q})\hat{Q} + Kp(\hat{Q}) - C^*(K) = 0,$$

$$p'(\hat{Q})\hat{Q} + (K+1)p(\hat{Q}) - C^*(K+1) = 0.$$

Hence, we have the following relationship:

$$C^*(K+1) - p(\hat{Q}) = C^*(K). \tag{5}$$

With this relationship defined in (5), firm 1 can choose the C (and thus) K that maximizes its profits. To determine this, we need firm 1's resulting profit level after the marginal firm exits. For this, the only important thing is the aggregated marginal costs among the remaining firms. If K firms remain in the market after firm(s) exit, the aggregate marginal cost would be

$$\sum_{k=1}^{K} c'_k = C(K+1) - c_H,$$

since if $K+1$ firms had remained, it would have cost c_H. Thus, if K firms remain in the market after firms exit, the equilibrium output $Q^*(K)$ is defined by the aggregate marginal costs

$$p'(Q^*(K))Q^*(K) + Kp(Q^*(K)) - (C^*(K+1) - c_H) = 0. \tag{6}$$

Alternatively, if $K - 1$ firms remain in the market after firms exit, then the condition is

$$p'(Q^*(K-1))Q^*(K-1) + (K-1)p(Q^*(K-1)) - (C^*(K) - c_H) = 0. \tag{7}$$

We will show that firm 1 achieves a higher payoff in the latter case than in the former case. If this is shown, then we can show that firm 1 is better off by predating as many high cost firms as possible, as long as predation is profitable. Since $C(K) = C(K+1) - p(\hat{Q})$, (7) becomes

$$p'(Q^*(K-1))Q^*(K-1) + (K-1)p(Q^*(K-1)) - (C^*(K+1) - p(\hat{Q}) - c_H) = 0,$$

which can be written as

$$p'(Q^*(K-1))Q^*(K-1)+Kp(Q^*(K-1))-(C^*(K+1)-c_H)+p(\hat{Q})-p(Q(K-1))=0.$$

That is,

$$p'(Q^*(K-1))Q^*(K-1)+Kp(Q^*(K-1))-(C^*(K+1)-c_H)=-p(\hat{Q})+p(Q^*(K-1))>0,$$

while from (6) we have

$$p'(Q^*(K))Q^*(K)+Kp(Q^*(K))-(C^*(K+1)-c_H)=0.$$

Since $p'(Q)Q+Kp(Q)$ is decreasing in Q by strategic substitutability, we have

$$Q^*(K-1)<Q^*(K).$$

Consequently since $\psi_k'(Q)<0$ (profits gross of investment costs are decreasing in Q),

$$\pi_1(K-1)>\pi_1(K).$$

Thus, as long as firm 1 can predate on high cost firms by transferring its technology, it should predate as many as it can. To summarize,

Lemma 4. Suppose that $c_1 \equiv c_L < c_2 = c_3 = \ldots = c_K \equiv c_H$ 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 4 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 possible firm rather than just a few. For instance, if the efficient firm could predate to a duopoly,

---

[12] Again this result can be reinterpreted in terms of entry deterrence. That is, we 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 (including a potential rivals) to transfer its technology to deter the additional entry.

then it always will rather do that rather than just drive out one or two firms. The market structure will have the fewest firms that predation will allow.

Lemma 4 might seem surprising given that in Example 1 when the efficient firm was slightly more efficient (c_L = .41), it was no longer profitable to predate to a duopoly. In the example it was assumed that the low cost firm transferred all of its technology to one of its high cost rivals, lowering the rival's cost to its own: $\Delta_{k'} = c_H - c_L$ = .18. However, if instead, the low cost firm made a slightly smaller transfer ($\Delta_{k'}$ = .17) to the high cost rival, then it can predate on all other high cost firms resulting in a duopoly. Moreover, with this slightly smaller transfer, the low cost firm's profits are greater than if it had transferred no technology. More importantly, Lemma 4 means that this technology transfer ($\Delta_{k'}$ = .17) is the most profitable strictly positive transfer. That is, this transfer of $\Delta_{k'}$ = .17 is superior to, say, a smaller transfer that predates on only ten firms even though this smaller transfer leaves the rival less efficient. It is straightforward to derive the exact transfer amount necessary.[13]

A requirement of Lemma 4 is that it must be profitable to predate on at least one firm (and if so then every possible firm should be preyed on) for predation to occur. That is, while it may be more profitable to prey on every firm possible than just one firm, it may be more profitable to prey on no firm as is highlighted by the next example.

Example 2: Unprofitable deterrence when entry is already partially restricted

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 with twenty firms in the market, predation by proxy was profitable. Suppose instead that there were only one low cost firm and three high cost firms in the market (or alternatively, in entry-deterrence case, there were only two inefficient firms

---

[13] 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 $\underline{\Delta} = 1 + c_L - 2c_H - (K - m + 2)\sqrt{F}$.

that could enter the duopoly market due to restricted entry). As in Example 1, it would still take a technology transfer of $\Delta_{k'} = .18$ to predate two high cost firms (and keep the market a duopoly), resulting in the same *ex post* profit with the technology transfer. However, it now earns a greater profit without any technology transfer (since there are fewer rivals in the market). As a result, in this case it is no longer profitable to predate because the low cost firm's profit with the transfer is less than its profit with no technology transfer. Or, to put it differently, in this case the market price is greater with no technology transfer. The same comments apply to the entry-deterrence case with restricted entry.

An implication of the example in the case of entry-deterrence is that a market with more firms all else equal is one in which predation is more likely to be profitable. In terms of entry-deterrence instead of predation, this implies that a market that has free entry can end up with *fewer* firms producing ex post than one with restricted entry. The example also suggests that, if the original number of firms in the market was determined by an entry condition (without restrictions to entry), then predation would always be profitable, although this would be a sufficient but not necessary condition.

To derive this sufficient condition for joint production to be profitable, we introduce a definition. When there is a low cost firm and many potential high cost entrants, we say that a market with K firms satisfies an **entry equilibrium condition** when

$$\pi_H(Q(K)) > 0 \geq \pi_H(Q(K+1)).$$

It is worthwhile to note that we are not assuming that the marginal entrant's profit is zero (and so the following does not rely on ignoring the integer constraint). The entry condition implies

$$\frac{\left(p(Q(K))-c_H\right)^2}{-p'(Q(K))} > \frac{\left(p(\hat{Q})-c_H\right)^2}{-p'(\hat{Q})} = F > \frac{\left(p(Q(K+1))-c_H\right)^2}{-p'(Q(K+1))}.$$

Since the optimal way to reduce the number of firm to $K-1$ is to transfer technology to a firm to

achieve $C^*(K)$ for K firms.

$$p'(Q^*(K-1))Q^*(K-1)+(K-1)p(Q^*(K-1))-(C^*(K)-c_H)=0.$$

Without technology transfer, $Q(K+1)>\hat{Q}$ holds by the entry condition. Thus, we have

$$p'(Q(K))Q(K)+Kp(Q(K))=C(K+1)-c_H>C^*(K+1)-c_H.$$

Therefore, since $p'(Q)Q+Kp(Q)$ is decreasing, we conclude

$$Q(K)>Q^*(K)>Q^*(K-1),$$

or

$$p(Q(K))<p(Q^*(K))<p(Q^*(K-1)).$$

This implies

$$\pi_1(Q(K))<\pi_1(Q^*(K-1)).$$

Hence, predating a high cost firm by technology transfer is beneficial. We have the following proposition.[14]

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

Our running example helps to emphasize three points that may not be immediate from proposition 2. First, that predation can radically change the market structure, going from a twenty-one firm oligopoly to a duopoly. Second, the remaining rival(s) can be more efficient than any of the

---

[14]If we drop the commonly made assumption that there are only two types of firms, the result is weakened. Since c_k's are now heterogeneous ($c_1 \leq c_2 \leq \ldots \leq c_K$), predating more firms tends to reduce the resulting market price and the resulting profits can be lower. Nonetheless, 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.

original rivals. Indeed, the structure may result in $K - m$ 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 potentially has an incentive to transfer technology so that the market is characterized instead by a few low cost oligopolists. Third, note that 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 (inefficient firms) who do not receive transfers: all firms obtain the higher price, but the efficient firm has a greater increase in output.

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 $\underline{K}+1^{\text{th}}$ firm, where

$$\underline{K} = \min_{K}\left\{K : \exists C \geq K \times c_L \;\; s.t. \; p'(\hat{Q})\hat{Q} + (K+1)p(\hat{Q}) - C = 0\right\}.$$

However, this imposes little restrictions on *how* the average cost is reduced, since our model satisfies the conditions for neutrality theorem by Bergstrom and Varian (1985). 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. 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.

6. Welfare effects of profit maximizing 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. Since joint production can profitably serve as a type of predation and drives out rivals or prevents entry, then there is some basis for their concern. In this section we analyze the welfare effects of profitable predation or entry deterrence using the more general heterogeneous cost structure among rival firms $(c_1 \leq c_2 \leq ... \leq c_K)$.

We begin by making some intuitive observations. Consider first the effect on consumer welfare. Since profitable predation must increase the price, consumers are clearly worse off. Turning to aggregate profits, we note that marginal cost and fixed costs (through exit/non-entry) decrease. Lahiri and Ono (1988) do show that welfare can decrease from a decrease in marginal costs, but that is driven by the cost reduction inducing more efficient firms to produce less, while with exit here the more efficient firm produces more. On the other hand, there is lost profit from those firms that exit, so the aggregate effect on profits is unclear. For this reason, the aggregate effect predation has on welfare is not immediate. Despite the negative effects that predation has (consumers harmed as well as those firm that exit), we can show that the net effect of profitable predation is for welfare to increase.

We begin our analysis by examining the welfare effects of profitable predation on the Kth firm as a result of a technology transfer that just drives firm K out. That is, firm K is indifferent between staying and exiting (that is, with the technology transfer to some other firm, firm K is earning zero profit, which by our tie-breaking rule means it would exit). To show the welfare effects, we will first ignore the welfare effects from the cost reduction and focus on the the effect of the Kth firm exiting. That is, consider two cases:

I. Firm K chooses to stay in. Total output is $\hat{Q}(K)$ and the market price is $p(\hat{Q}(K))$.

II. Firm K chooses to exit. Total output is $Q^*(K-1)$ and the market price is $p(Q^*(K-1))$

We will show that the social welfare in case 2 is higher than the one in case 1.

Given the assumption, we have

$$\pi_K(p(\hat{Q}(K))) = \frac{(p(\hat{Q})-c_K)^2}{-p'(\hat{Q}(K))} - F = 0. \, ^{15} \tag{8}$$

Total outputs $\hat{Q}(K)$ and $Q^*(K-1)$ are determined by

$$p'(\hat{Q})\hat{Q} + Kp(\hat{Q}) - \sum_{k=1}^{K} c_k = 0, \tag{9}$$

$$p'(Q^*(K-1))Q^*(K-1) + (K-1)p(Q^*(K-1)) - \sum_{k=1}^{K-1} c_k = 0. \tag{10}$$

Now, the total variable cost of production is written as (K firm case with $\sum_{k=1}^{K} q_k = Q$),

$$VC(Q;c,K) = \sum_{k=1}^{K} c_k q_k = c_1 Q + (c_2 - c_1)(Q - q_1) + ... + (c_K - c_{K-1})\left(Q - \sum_{k=1}^{K-1} q_k\right).$$

Thus, the social welfare in the first case is written as

$$SW^I = \int_0^{\hat{Q}(K)} p(Q)dQ - VC(\hat{Q}(K),c,K) - KF,$$

and similarly the social welfare in the second case is written as

$$SW^{II} = \int_0^{Q^*(K-1)} p(Q)dQ - VC(Q^*(K-1),c,K-1) - (K-1)F.$$

Note that $\hat{q}_k(K) < q_k^*(K-1)$ for all k's since $p(\hat{Q}(K)) > p(Q^*(K-1))$ holds. This implies that

$\hat{q}_K > \hat{Q}(K) - Q^*(K-1)$, since $\hat{Q}(K) = \sum_{k=1}^{K} \hat{q}_k$ and $Q^*(K-1) = \sum_{k=1}^{K-1} q_k^*(K-1)$. With this we can

prove the following (the proof is in the appendix).

Lemma 5. Suppose that there are K firms and the Kth firm (the highest cost firm) is indifferent between entering and not entering in the equilibrium. Then, we have:

---

[15] Because costs are increasing in k, $\hat{Q}(K) \le \hat{Q}(K-1)$ for all K.

1. Consumers are worse off by the exit of the Kth firm.

2. The first $Q^*(K-1)$ units are produced more efficiently with $K-1$ than with K firms.

3. With K firms, the last $\hat{Q}(K) - Q^*(K-1)$ units are produced by the highest cost K^{th} firm.

4. If the output reduction from predation satisfies $\hat{Q}(K) - Q^*(K-1) \leq \hat{q}_K(K) \times (K-1)/K$ then the

    welfare loss from output reduction is less than the fixed cost of having the Kth firm in the market:

    $$\int_{Q^*(K-1)}^{\hat{Q}(K)} (p(Q) - c_K) dQ \leq (p(\hat{Q}(K)) - c_K)\hat{q}_K(K) = F,$$

where $\hat{q}_K$ denote the highest cost firm's output level in equilibrium with K firms.[16]

Note that since we were considering the effect of profitable predation on an arbitrary K^{th} firm, it then follows that profitable predation on *every* firm is welfare improving.

There are several reasons why the condition for 5.4, $\hat{Q}(K) - Q^*(K-1) \leq \hat{q}_K(K) \times (K-1)/K$, is not overly restrictive. First note that even if there were no technology change and firm K exited then the output reduction is always less than K^{th} firm's output: $\hat{Q}(K) - Q^*(K-1) \leq \hat{q}_K(K)$. This follows because with the $K-1$ firms equilibrium price is higher and hence all $K-1$ firms produce more, than when there are K firms in the market: i.e., $\hat{q}_k(K) < q_k^*(K-1)$ holds for all $k = 1, \ldots K-1$. Thus, for large K, it is not unreasonable to assume

$$\hat{Q}(K) - Q^*(K-1) \leq \hat{q}_K \times (K-1)/K.$$

Second, if demand is linear the above condition is always satisfied. Even with a small number of *symmetric* firms (most conservative case, $K = 3$: we need at least three firms to be consistent with deterrence or predation story with technology transfer: one low cost firm, one firm

---

[16] Mankiw and Whinston (1986) show that *infinitesimal* entry is always excessive, while here we must consider an integer firm. With the integer constraint, they show that one more than the free entry number is always inefficient.

gets the technology transfer and one firm exits/does not enter), it is easy to satisfy the condition. Let

$c = 0$ and p and $p'(Q) = -1$. Then, $\hat{q}_i(K) = \dfrac{1}{4}$ and $q_i^*(K-1) = \dfrac{1}{3}$ for all i, thus $\hat{Q}(K) - Q^*(K-1)$

$= 1/12$ and $\dfrac{K}{K-1}\left(\hat{Q}(K) - Q^*(K-1)\right) = \dfrac{1}{8}$. Thus, the inequality is easy to satisfy.

Finally, note that the condition is not a necessary condition since we have not accounted for the cost reduction some rival obtained that induces this exit. We conclude then that driving out the Kth through predation would improve social welfare fairly generally except for possibly some special demand functions.

Now by utilizing Lemma 5, we can establish the welfare effect of predation/deterrence. Suppose that there are K firms originally without any technology transfer, and that predating on m firms by transferring technology is beneficial to the low cost firm.[17] This implies that the original price $p(Q^e(K))$ is less than the price after the optimal predation of m firms $p(Q^*(K-m))$, where superscript e denotes the original equilibrium without technology transfer.. This fact has a strong implication: all firms $1,\ldots,K-m$ increase their output levels under $p = p(Q^*(K-m))$: $q_k^*(K-m) \geq q_k^e(K)$ for all $1,\ldots,K-m$. This means that the first $Q^*(K-m)$ units are produced at lower total variable cost after predation even without technology transfer (Lemma 5.2). Thus, what is left to show is that the welfare reduction by a reduction in output due to predation is less than the fixed cost. From Lemma 5.3 and 5.4, we know that if we compare the $K-m$ firm case with the optimal technology transfer and a $K-m+1$ firm case, then the former dominates the latter in social welfare if

$\hat{q}_{K-m}(K-m)\dfrac{K-m-1}{K-m} \geq \hat{Q}(K-m+1) - Q^*(K-m)$ holds. We can show that the output reduction by predating m firms is bounded above by $\hat{Q}(K-m+1) - Q^*(K-m)$, i.e., $Q^e(K) - Q^*(K-m) \leq$

$\hat{Q}(K-m+1)-Q^*(K-m)$, since $Q^*(K-m) < Q^e(K) \le \hat{Q}(K)\le \hat{Q}(K-m+1)$ holds. The last inequality comes from the marginal firm achieves zero profit if it is in: since $c_{K-m+1} \le c_K$, $p(\hat{Q}(K-m+1)) \le p(\hat{Q}(K))$ must hold, which implies $\hat{Q}(K)\le \hat{Q}(K-m+1)$. Thus, by Lemma 5.4, the welfare loss from an output reduction by predating m firms is dominated by a firm's fixed cost F. This result is summarized as follows:

Proposition 3. Suppose that there are K firms in the market originally, and that it is profit maximizing for the low cost firm to prey on m firms through a technology transfer. Then, consumers are worse off, but aggregate profits and social welfare increases if

$$\hat{q}_{K-m+1}(K-m+1)\frac{K-m-1}{K-m} \ge \hat{Q}(K-m+1)-Q^*(K-m).$$

Note that the above sufficient condition only considers fixed-cost-saving from only one firm's exit. Predation saves fixed costs by the number of predated firms m, so if m is more than one social welfare can be improved even if the above sufficient condition is violated. The policy implication of this proposition is that predation by proxy increases market price and hurts consumers, but cost-saving effect of predation actually can increase overall social welfare. Thus, while a predator is driving firms out of the market for its own gain and this act appears to be anti-competitive, allowing joint production with such predation may actually make sense for policy makers.

We note that the proof does not turn on how the predation occurs: whether the predator chooses a few firms to receive a large transfer or many firms to receive a small transfer. However, by Salant and Shaffer (1999) fewer firms receiving a larger transfer is more efficient than many firms receiving a small transfer. As intuitively one would expect the former to be the approach used by the predator, then the welfare gains from predation could even be greater than suggested.

We close this section by noting that the proof of proposition 3 does not depend on the entry

condition, but does require that there are no exit barriers. Thus, even with restricted entry the profit maximizing deterrence through technology transfers is welfare improving. Likewise, in a market with an exogenous number of firms (that is, the number of competing firms was not determined by the efficiency condition), the profit maximizing amount of predation is welfare improving. Finally, the importance of exit is emphasized by comparing our results to (Lahiri and Ono 1988) who found that a small technological improvement to an inefficient firm can be welfare reducing. We find that so long as exit is possible, which is not considered by Lahiri and Ono (1988), and this transfer is driven by profitable predation then it is welfare improving rather than welfare worsening.

7. 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. That is, our initial impetus was to answer the question as to why would a company help their rivals to make huge productivity gains, which is characteristic of many joint production agreements. We find that 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 or deterrent behavior, resulting in a smaller number of firms and a higher price in the market. We call this the "predation effect."

In examining this predation "by proxy" we allow for *partial* technology transfers to (possibly) *multiple* firms. We find that profitable predation results in the market price increasing. Although this price increase reduces consumer surplus, social welfare (and thus, industry profit) normally increases from the profit-maximizing amount of predatory technology transfers. To give context to this predation effect we determine the conditions for predation by proxy in the standard dominant firm framework, that is, when there is one low cost firm and multiple high cost firms. This is the framework used, e.g., in the licensing literature. We find that in this case 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, this "predation" is *always* profitable when high cost firms can enter into the market freely.

The policy implications of our analysis are as follows. Just as work in the 1980s broaden the perspective on joint production or mergers by including the effect of such agreements on nonmembers' strategies, we extended the perspective to considering the effects of the possibility of entry or exit.[18] As a result, we find there can be cause for the original suspicion that the members of the joint production are using the agreement to affect the market to their advantage. That is, policy makers should consider whether the joint venture could potentially drive out weaker rivals or prevent other firms from entering as the driving force behind the venture. The former may have been part of the concern with respect to Chrysler in the case of NUMMI.[19] However, our analysis also suggests that if this is the driving force, then it may well be welfare enhancing for the policy maker to allow the joint production.

Finally, we consider the empirical implications of our analysis. Starting with Eckbo (1983, 1985) there has been a good amount of research examining the effect of mergers on horizontal rivals. The idea being that if the merger is for collusive reason – resulting in higher prices for the merged firm – then the horizontal rivals should benefit from the merger, which should be reflected in the stock prices. If instead the merger is for cost reason, then horizontal rivals should be harmed. Our model suggests that joint production or mergers should have *differential* effects on rivals. Specifically, those horizontal rivals (or potential entrants) that are relatively inefficient should have a

---

[18] The role of entry has been considered in the past, but either in terms of a member of the joint venture being a potential entrant (who therefore would not enter) or if entry barriers *prevent* entry so that the number of rivals could be assumed fixed. Of course, entry by and of itself is an extensively studied topic.

[19] There is also the possibility that NUMMI had a deterrence effect as well. In the 1980s Toyota may well have been concerned with new manufactures (e.g., Korean manufacturers) and attempted expansion (or re-entry) by others. Of course, even 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.

negative effect on their stock prices, while the more efficient rivals should have a positive effect on their stock prices. This is exactly what Singal (1996) found in the airline industry: "An examination of abnormal stock returns to individual rival firms reveals the existence of rival firms that are hurt, and of rival firms that are helped, by mergers." Finally our model also predicts *price* increases when predation by proxy is the motivating reason along with increased concentration, which is consistent with the findings in, e.g., Kim and Singal (1993).

Appendix

Lemma 3. When $\Delta_k = 0$, firm k does not engage in a joint production if it does not reduce the number of active firms.

Proof. From the main body we found that if $\Delta_k = 0$, then firm k gains from a joint production if

$$\psi_k(Q) = \frac{\left(p(Q) - c_k\right)^2}{-p'(Q)} \tag{A1}$$

is decreasing in Q in the interval (Q^*, Q^J). Differentiating the RHS of (A1) with respect to Q, we obtain

$$\frac{2\left(p(Q) - c_k\right)p'(Q)\left(-p'(Q)\right) + \left(p(Q) - c_k\right)^2 p''(Q)}{\left(-p'(Q)\right)^2}$$

$$= \frac{\left(p(Q) - c_k\right)}{\left(-p'(Q)\right)^2} \times \left[-2(p'(Q))^2 + \left(p(Q) - c_k\right)p''(Q)\right].$$

Thus $\mathrm{Sgn}[\psi_k'(Q)]$ depends on $\mathrm{Sgn}\left[-2(p'(Q))^2 + \left(p(Q) - c_k\right)p''(Q)\right]$, which can be determined as follows. The first and the second order conditions for firm k's profit maximization are:

$$\frac{\partial \pi^k}{\partial q_k} = p'(Q)q_k + p(Q) - c_k = 0,$$

$$\frac{\partial^2 \pi^k}{\partial q_k^2} = p''(Q)q_k + 2p'(Q) \leq 0.$$

The second order condition can be written as (by using the first order condition),

$$p''(Q) \times \frac{p(Q) - c_k}{-p'(Q)} + 2p'(Q) \leq 0.$$

Since $p'(Q) < 0$, $-2(p'(Q))^2 + \left(p(Q) - c_k\right)p''(Q) < 0$ and so $\psi_k'(Q) \leq 0$.//

Lemma 5. Suppose that there are K firms and the Kth firm (the highest cost firm) is indifferent

between entering and not entering in the equilibrium. Then, we have:

1. Consumers are worse off by the exit of the Kth firm.

2. The first $Q^*(K-1)$ units are produced more efficiently with $K-1$ than with K firms.

3. With K firms, the last $\hat{Q}(K)-Q^*(K-1)$ units are produced by the highest cost K^{th} firm.

4. If the output reduction from predation $\hat{Q}(K)-Q^*(K-1) \leq \hat{q}_K(K)\times(K-1)/K$ then the welfare

   loss from output reduction is less than the fixed cost of having the Kth firm in the market:

$$\int_{Q^*(K-1)}^{\hat{Q}(K)}(p(Q)-c_K)dQ \leq (p(\hat{Q}(K))-c_K)\hat{q}_K(K)=F,$$

where $\hat{q}_K$ denote the highest cost firm's output level in equilibrium with K firms.

Proof.   Statement   5.1   follows   directly   from $p(Q^*(K-1))>p(\hat{Q}(K))$.   Moreover,

$p(Q^*(K-1))>p(\hat{Q}(K))$ also implies that all firms $1,\ldots,K-1$ produce more after predation. Since

$\hat{Q}(K)=\sum_{k=1}^{K}\hat{q}_k(K)=\sum_{k=1}^{K-1}\hat{q}_k(K)+\hat{q}_K(K) <Q^*(K-1)+\hat{q}_K(K)$, 5.3 holds.   Using the welfare

definitions, the welfare with firm K entering less that of firm K not entering is $SW^I - SW^{II}$

$$= \int_{Q^*(K-1)}^{\hat{Q}(K)}p(Q)dQ-\left[\sum_{k=1}^{K}c_k\hat{q}_k(K)-c_K\times(\hat{Q}(K)-Q^*(K-1))-\sum_{k=1}^{K-1}c_kq_k^*(K-1)\right]$$

$$-c_K\times(\hat{Q}(K)-Q^*(K-1))-F$$

$$= \int_{Q^*(K-1)}^{\hat{Q}(K)}p(Q)dQ-c_K(\hat{Q}(K)-Q^*(K-1))-F$$

$$-\left[\sum_{k=1}^{K-2}(c_{k+1}-c_k)\left(\hat{q}_k(K)-q_k^*(K-1)\right)+(c_K-c_{K-1})\left(Q^*(K-1)-\sum_{k'=1}^{K-2}\hat{q}_{k'}(K-1)\right)\right]$$

Note the contents of the bracket is positive, since for all $k = 1,\ldots,K-1$, $\hat{q}_k(K)>q_k^*(K-1)$ holds.

Thus, 5.2 has been shown.   Finally, since 5.3 guarantees that the reduced output by predation is

produced by firm K, 5.4 – welfare with the Kth not entering is greater $(SW^I < SW^{II})$ – is proved if

$$\int_{Q^*(K-1)}^{\hat{Q}(K)} \left(p(Q) - c_K \right) dQ \le \left(p(\hat{Q}(K)) - c_K \right) \hat{q}_K.$$

A sufficient condition for this is,

$$\left(p(Q^*(K-1)) - c_K \right) \left(\hat{Q}(K) - Q^*(K-1) \right) \le \left(p(\hat{Q}(K)) - c_K \right) \hat{q}_K(K). \tag{A2}$$

Now, using the definitions of $Q^*(K-1)$ and $\hat{Q}(K)$ (i.e., subtracting equation (10) from (9)), we obtain,

$$\left[p'(\hat{Q}(K))\hat{Q}(K) - p'(Q^*(K-1))Q^*(K-1) \right] - (K-1)\left(p(Q^*(K-1)) - p(\hat{Q}(K)) \right)$$

$$+ p(\hat{Q}(K)) - c_K = 0.$$

Differentiating $p'(Q)Q$ with respect to Q, we obtain

$$\frac{dp'(Q)Q}{dQ} = p''(Q)Q + p'(Q) \le 0.$$

The inequality holds by the strategic substitute assumption. Thus, the contents of the bracket are non-positive. This implies

$$-(K-1)\left(p(Q^*(K-1)) - p(\hat{Q}) \right) + p(\hat{Q}) - c_K \ge 0,$$

or

$$\frac{p(\hat{Q}(K)) - c_K}{K-1} \ge p(Q^*(K-1)) - p(\hat{Q}(K)).$$

By rewriting (A2), we obtain

$$(p(\hat{Q}(K)) - c_K)\hat{q}_K(K) \ge \left(p(Q^*(K-1)) - c_K \right) \left(\hat{Q}(K) - Q^*(K-1) \right)$$

$$= \left((p(Q^*(K-1)) - p(\hat{Q}(K))) + (p(\hat{Q}(K)) - c_K) \right) \left(\hat{Q}(K) - Q^*(K-1) \right),$$

or

$$(p(\hat{Q}(K)) - c_K)\left(\hat{q}_K(K) - \left(\hat{Q}(K) - Q^*(K-1) \right) \right) \ge \left(p(Q^*(K-1)) - p(\hat{Q}(K)) \right) \left(\hat{Q}(K) - Q^*(K-1) \right).$$

Thus, for (A2) to hold, it suffices to show

$$\hat{q}_K(K) - \left(\hat{Q}(K) - Q^*(K-1)\right) \geq \frac{1}{K-1}\left(\hat{Q}(K) - Q^*(K-1)\right),$$

or

$$\hat{q}_K(K) \geq \frac{K}{K-1}\left(\hat{Q}(K) - Q^*(K-1)\right).$$

We proved the desired result.//

References

Bergstrom, T.C., and H.R. Varian, 1985, "When are Nash Equilibria Independent of the Distributino of Agents' Characteristics?" *The Review of Economic Studies*, 52(4), pp. 715-718.

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.

Brown, W., 1984, "Joint Car Output Not Necessary in GM-Toyota Deal," The Washington Post, May 31, Final Edition, Business & Finance; C12

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, "The Unilateral Incentives for Technology Transfers: Predation by Proxy," Boston College Working Papers in Economics 676.

Creane, A. and H. Konishi, 2008, "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.

Davidson, C. and A. Mukherjee, 2008, Horizontal mergers with free entry, *International Journal of*

Industrial Organization, 25(1), 157-172.

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

Dixit, A., 1980, "The Role of Investment in Entry Deterrence," *The Economic Journal*, 90, 95-106.

Duerr, E.C., M.S. Duerr, G.R. Ungson and Y-Y. Wong, 2005, "Evaluating a Joint Venture: NUMMI at Age 20, *International Journal of Business and Economy*, 6(1), 111-135.

Eckbo, B.E., 1983, "Horizontal Mergers, Collusion and Stockholder Wealth," *Journal of Financial Economics*, 11(1), pp.241-273.

Eckbo, B.E., 1985, ""Mergers and the Market Concentration Doctrine: Evidence from the Capital Market," *Journal of Business*, 58(3), pp. 325-349.

Etro, F., 2006, Aggressive Leaders, *The Rand Journal of Economics*, 37(1), pp. 146-154.

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., S.S. Oren, and Y. Tauman, 1992, "Optimal Licensing of Cost-reducing Innovation," *Journal of Mathematical Economics*, 21, 483-508.

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.I. and Zang, I., 1990, "The Limits of Monopolization through Acquisition," *Quarterly*

Journal of Economics, 105(2): 465-499.

Kim, E.H., and V. Singal, 1993, "Mergers and Market Power: Evidence from the Airline Industry," *American Economic Review*, 83, 549-569.

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.

Rocket, K., 1990, "Choosing the Competition and Patent Licensing," *The Rand Journal of Economics*, 21(1), 161-171.

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.

Sen, D. and Y. Tauman, 2007, "General Licensing Schemes for a Cost-reducing Innovation," *Games and Economic Behavior*, 59, 163-186.

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.

Singal, V., 1996, "Airline Mergers and Competition: An Integration of Stock and Product Price Effects," *The Journal of Business*, 69(2), pp. 233-268

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.

Weiss, S.E., M.T. Hogan, J.W.Chai, E.J. Meigher, E.F. Glynn, Jr., and D.C. Cuneo, "The General Motors-Toyota Joint Venture, 1982–84, *International Negotiation* **1:** 277–292, 1996.