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Licensing technology and foreclosure*

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Abstract

We consider an industry where one firm with a superior technology competes for market shares with several rivals. The owner of the superior technology (the dominant firm) can license or transfer the source of its dominance to a subset of rivals. Allowing the non-license takers to remain active in the market is a drain on the profit of the insiders, and we demonstrate that the dominant firm will only make a transfer of the superior technology if it can be used to foreclose some rival firms. Foreclosure of a subset of firms may thus be the outcome even without restrictions on the licensing schemes. Moreover, we show that when licensing is profitable, the dominant firm will prefer a complete transfer even if a partial transfer can be made.

Keywords: Licensing, foreclosure, contest

JEL Classification: D21, L24

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1 Introduction

Being in possession of superior technology may give a firm a competitive edge over rivals, but sometimes the technology owner may voluntarily choose to license it to rival firms and by doing so reduce its own competitive advantage. A similar issue arises in industries where some firms own infrastructure that is either essential or costly to replicate, and where the owners of such infrastructure may choose to award rival firms access to the infrastructure. We allow the owner of the superior technology to license its technology to a sub-set of the other firms. All firms but the one with the superior technology are assumed to be *ex ante* symmetric. Firms may still be active in the product market without licensing, but the profitability of being in the market naturally depends on the number of other firms and the extent to which licensing is selective. In the present model the technology can be adopted by the adoptees at no cost other than the license fee; this may be positive, negative or zero. We use a contest type model, where firms compete for a share of a market of exogenously given value. There is consequently no added value of licensing on the demand side, neither through coordination nor through price effects. The effect of licensing is related to the effect on effort costs, where the R&D undertaken only affects the distribution of market shares but not the size. This could be thought of as the case of competing for market shares in a mature market.

The main message from the paper is that foreclosure of a subset of firms may be the outcome even without restrictions on the licensing schemes. To transfer the superior technology to a subset of rivals may be used as a tool to foreclose the non-license takers from the market. We demonstrate that the dominant firm will only make a transfer of the superior technology if it can be used to foreclose some rival firms. The reason for this is that active outsiders (i.e., firms that do not obtain licenses) are a drain on the insiders' profit. Licensing only occurs if the licensor is able to foreclose all rival firms but the licensees, and trades are more likely the larger the number of players at the outset.

To check the robustness of the results, we open for the possibility that the superior firm can transfer an intermediate quality of technology to rivals (i.e. one that is better than the rivals' initial technology, but not as efficient as the one used by the dominant actor). The motive to foreclose is so strong that the superior firm would prefer to make the best technology available since this also forecloses as many rivals as possible.

The effort undertaken by the participating firms may be interpreted as any type of innovation or investment that may affect the allocation of market shares among the firms. The number of potential firms in the industry is exogenously given, but we investigate the importance of the number of initial firms on both the feasibility of licensing and the social desirability of such licensing. As such, our focus is similar to Vilasuso and Frascatore (2000) who consider the alignment of private and societal incentives in a traditional R&D setting where invention reduces marginal cost of production. Our analysis is complementary since technology transfer can work through another channel by affecting the number of competitors.

Shephard (1987) presents a model where the buyers of a new proprietary product care about both input price and quality, and where licensing may ensure quality competition. Without such quality competition buyers will expect that the seller reduces quality *ex post* of the buyers' purchase decision, which affects demand negatively. With credible commitment to quality competition there is a demand-enhancing effect. A similar kind of opportunism effect is discussed in Farrell and Gallini (1988), where buyers may not want to purchase a product or service which implies set-up costs if *ex post* exploitation through high prices is possible. To avoid this, commitment to low future prices may be achieved through licensing at low royalties or as an open access platform. Conner (1995) analyses the demand effect of cloning (or transfer of technology) to rival firms in a setting with network externalities, and shows that such clones may be valuable to the innovating firm. In our setting, we abstract from the demand effects to focus on the use of licensing as a foreclosure device.

Katz and Shapiro (1985) analyse a three-stage R&D game with two downstream firms, and they show that major innovations will not be licensed, but that minor innovations may be licensed by equally efficient firms. Although our set-up is different to theirs, we obtain a similar result. To achieve a pure strategy Nash equilibrium that involves licensing, the difference between the superior technology and the technology available to the other firms cannot be too large. Gallini (1984) considers the use of licensing in the product market as a strategic device to deter rivals from entering into R&D activity. In the present analysis, the innovation is already realised and we only consider when and whether licensing can occur. Rockett (1990) demonstrates how licensing can be used to choose the competitors ("weak" or "strong"), through changing the rules and conditions of the post-patent entry game. By licensing to weak competitors, the licensor is able to enjoy monopoly rent after the patent expires by crowding the market. Yi (1998) investigates licensing when potential licensees differ in the absorptive capacities, and finds that it is optimal to license exclusively to the strong rival. Erutku and Richelle (2006) consider heterogeneous firms that may produce differentiated products, and show a licensor can use non-linear tariffs to extract the full monopoly rent from an invention. Eswaran (1994) analyses a situation where an incumbent can license its technology to firms that are currently not active in the market (i.e., without a viable technology) to deter entry by a potential rival with an alternative technology.[1] Licensing its technology to firms formerly outside the market raises the level of competition, but by using a combination of royalties and a fixed fee the licensor is able to profitably license its technology. In the present analysis, all firms have access to a viable technology and the owner of the superior technology may decide to license to some or all of the other active firms.

What appears to be surprising in our model compared to the previous literature is that even without restrictions on licensing schemes there will be foreclosure of a subset of firms. The result is a consequence of the trade-off between losing competitive advantage compared to the rivals and capturing license fees. By foreclosing a sub-set of firms, there are fewer firms that compete for market share.[2]

Section 2 analyses the case in which only the best available technology can be

[1] A similar issue is investigated in Yi (1999).

[2] This motive for voluntary disclosure of information is quite different to those often mentioned; for example, Harhoff et al. (2003) in their review of the relevant literature, cite low values of patent rights, costs involved in secrecy, and reputation-building as possible motives for freely revealing details of technology to rivals.

transferred, and Section 3 looks at the transfer of technology of intermediate quality. Section 4 sums up the findings an presents policy implications.

2 The model

There are $n+1$ firms that compete for a share of a total market of value V. Capturing market share involves making a sunk investment of some kind; these investments can have several interpretations such as investments in product promotion or essential infrastructure. Let firm 0 be in possession of an investment technology that has marginal cost 1. All other firms $j = \{1, .., n\}$ have a technology with marginal cost $c > 1$. Investments are denoted by $\widehat{x}_0$ and $\widehat{x}_j$ and are irretrievable. The market share (m) of a firm is equal to its investment relative to the sum of investments:

$$
\begin{aligned}
m_0 &= \frac{\widehat{x}_0}{\widehat{x}_0 + \sum_{s=1}^{n} \widehat{x}_s} \qquad (1)\\
m_j &= \frac{\widehat{x}_j}{\widehat{x}_0 + \sum_{s=1}^{n} \widehat{x}_s}, \quad j = \{1, .., n\}
\end{aligned}
$$

This formulation has been often used in the contest literature, following the seminal work by Tullock (1980)[3]. In a market share setting, Bell et al. (1975) axiomatized functions in (1) where investments were advertising expenditures, and for a recent application of this framework see Barros and Sørgard (2005).

2.1 Benchmark: No licensing

When each firm uses its initial technology, the expected payoffs are given by

$$
\begin{aligned}
\widehat{\pi}_0 &= \frac{\widehat{x}_0 V}{\widehat{x}_0 + \sum_{s=1}^{n} \widehat{x}_s} - \widehat{x}_0 \\
\widehat{\pi}_j &= \frac{\widehat{x}_j V}{\widehat{x}_0 + \sum_{s=1}^{n} \widehat{x}_s} - c\widehat{x}_j, j = \{1, ..., n\}
\end{aligned}
$$

First-order conditions defining an interior maximum for $\widehat{x}_0$ and $\widehat{x}_j$ are given by

[3] For many contest type applications of this function see Konrad (2006).

$$\begin{aligned}
\frac{\sum_{s=1}^{n} \widehat{x}_s V}{(\widehat{x}_0 + \sum_{s=1}^{n} \widehat{x}_s)^2} - 1 &= 0 \\
\frac{\widehat{x}_0 + \sum_{s \neq j} \widehat{x}_s V}{(\widehat{x}_0 + \sum_{s=1}^{n} \widehat{x}_s)^2} - c &= 0, j = \{1, ..., n\}
\end{aligned}$$

Equilibrium investments and expected payoffs are then easily verified to be

$$\begin{aligned}
\widehat{x}_0^* &= \frac{Vn(n(c-1)+1)}{(cn+1)^2} \\
\widehat{x}_j^* &= \frac{Vn}{(cn+1)^2}, \quad j = \{1, ..., n\} \\
\widehat{\pi}_0^* &= \frac{(n(c-1)+1)^2 V}{(cn+1)^2} = \widehat{x}_0^*(c - 1 + \frac{1}{n}) \qquad (2) \\
\widehat{\pi}_j^* &= \frac{V}{(cn+1)^2} = \frac{\widehat{x}_j^*}{n}, \quad j = \{1, ..., n\} \qquad (3)
\end{aligned}$$

$$W \equiv \widehat{\pi}_0^* + n\widehat{\pi}_j^* = \frac{(n(c-1)+1)^2 V}{(cn+1)^2} + n\frac{V}{(cn+1)^2}$$

where W is total welfare. The form of $\widehat{\pi}_0^*$ emphasizes the two sources of profit that firm 0 has in this model; profit increases the better 0's technology compared to others ($\frac{\partial \widehat{\pi}_0^*}{\partial c} > 0$), and the lower the number of rivals that compete for market share ($\frac{\partial \widehat{\pi}_0^*}{\partial n} < 0$).

2.1.1 Licensing

Suppose now that firm 0 can sell or license its technology to $k \leq n$ of the other firms for a price of t. Hence, with licensing we have $k+1$ firms with the new technology, and $n-k$ without. Denote the set of the k *ex ante* outsiders with access to the superior technology by set T and the $n-k$ without as set NT. We assume that there are no restrictions on the licensing schemes. Although the price t can be both positive and negative, the licensees in the present model will benefit from implementing the superior technology and are therefore prepared to pay a positive price $t > 0$.[4] The expected payoffs of firm 0, $j \in T$, and $i \in NT$ are then given by

$$\begin{aligned}
\pi_0 &= \frac{x_0 V}{x_0 + \sum_{s\in T} x_s + \sum_{v\in NT} x_v} - x_0 + kt \\
\pi_j &= \frac{x_j V}{x_0 + \sum_{s\in T} x_s + \sum_{v\in NT} x_v} - x_j - t,\ j \in T \\
\pi_i &= \frac{x_i V}{x_0 + \sum_{s\in T} x_s + \sum_{v\in NT} x_v} - cx_i,\ i \in NT
\end{aligned} \tag{4}$$

An interior equilibrium for investments is characterized by the following first-order conditions:

$$\begin{aligned}
\frac{\partial \pi_0}{\partial x_0} &= \frac{\left(\sum_{s\in T} x_s + \sum_{v\in NT} x_v\right) V}{\left(x_0 + \sum_{s\in T} x_s + \sum_{v\in NT} x_v\right)^2} - 1 = 0 \\
\frac{\partial \pi_j}{\partial x_j} &= \frac{\left(x_0 + \sum_{s\neq j\in T} x_s + \sum_{v\in NT} x_v\right) V}{\left(x_0 + \sum_{s\in T} x_s + \sum_{v\in NT} x_v\right)^2} - 1 = 0,\ j \in T \\
\frac{\partial \pi_i}{\partial x_i} &= \frac{\left(x_0 + \sum_{s\in T} x_s + \sum_{v\neq i\in NT} x_v\right) V}{\left(x_0 + \sum_{s\in T} x_s + \sum_{v\in NT} x_v\right)^2} - c = 0,\ i \in NT
\end{aligned} \tag{5}$$

The problems that player 0 and each member of T have to solve are identical, as is the maximisation problem for each $i \in NT$. Posit then that $x_0 = x_j \equiv x\ \forall\ j \in T$ and $x_i \equiv y\ \forall\ i \in NT$. Then (5) can be rewritten as

$$\begin{aligned}
\frac{(kx + (n-k)y)\, V}{((k+1)x + (n-k)y)^2} - 1 &= 0 \\
\frac{((k+1)x + (n-k-1)y)\, V}{((k+1)x + (n-k)y)^2} - c &= 0,\ i \in NT
\end{aligned} \tag{6}$$

From these two equations, the following relative relationship between x and y emerges:

[4]Eswaran (1994) argues that firms with technological capabilities of their own may use reverse engineering on the technology acquired from the licensor to avoid future payment of royalties, and that this is an argument for selling the technology through a fixed fee payment rather than renting it out by using royalties.

$$x = \frac{(n-k)(c-1)+1}{1+k(1-c)} y \tag{7}$$

The numerator in (7) is always positive and the denominator is positive for

$$\frac{1}{c-1} > k \tag{8}$$

Since an equilibrium involving some transfer of technology in which all n firms are active has $k \geq 1$ we can state the following result immediately.

Proposition 1 *There is no interior pure strategy Nash equilibrium involving the transfer of technology for* $c > 2$*, given that all firms are active.*

When the less efficient players are at a strong disadvantage ($c > 2$) it does not pay for the efficient firm to allow others to become more efficient whilst at the same time having some players participating that do not pay a licensing fee to firm 0.

2.1.2 Licensing without foreclosure

Suppose now that (8) is fulfilled, i.e., $c \in (1, 2]$, so that all firms have positive investment in equilibrium irrespective of their type of technology; we proceed to characterize the pure strategy Nash equilibrium. Using (7) in (6) gives the following equilibrium investments:

$$\begin{aligned} x^* &= \frac{Vn((n-k)(c-1)+1)}{((n-k)c+k+1)^2} \\ y^* &= \frac{Vn(1+k(1-c))}{((n-k)c+k+1)^2} \end{aligned} \tag{9}$$

Inserting (9) into (4) gives the equilibrium expected payoffs as

$$\begin{aligned} \pi_0^*(n,k) &= \frac{V((n-k)(c-1)+1)^2}{((n-k)c+k+1)^2} + tk \\ \pi_j^*(n,k) &= \frac{V((n-k)(c-1)+1)^2}{((n-k)c+k+1)^2} - t, j \in T \\ \pi_i^*(n,k) &= \frac{V((k(c-1)-1)^2}{((n-k)c+k+1)^2}, i \in NT \end{aligned} \tag{10}$$

Sale of the more efficient technology is profitable for 0 if $\pi_0^* \geq \widehat{\pi}_0^*$, and those who are offered the new technology wish to buy as long as $\pi_j^* \geq \widehat{\pi}_j^*$ from (3).

Technology sharing through licensing agreements is said to be feasible if such an agreement is in the interest of both the licensor and the licensees. In order to look at the feasibility of licensing agreements, consider the payoff of the group of "insiders", i.e. firms that have the best technology consisting of firm 0 and $j \in T$. The aggregate profit of this group increases after technology transfer if

$$\pi_0^*(n,k) + k\pi_j^*(n,k) > \widehat{\pi}_0^* + k\widehat{\pi}_j^* \tag{11}$$

since the licensing fee is just an internal transfer within the group. Without considering the licensing fee, it is easy to verify that 0 gets a lower payoff following technology transfer, and the other insiders experience an increase. The licensor will not accept to share its technology without side payment, and the licensees are willing to pay a positive price for access to the technology, which implies that feasibility requires a transfer to the licensor.

If (11) is satisfied, it is possible to compensate firm 0 adequately for the reduction in expected payoff. Using (10), (2) and (3), (11) is satisfied as long as

$$n \geq k > \frac{2\,(cn+1)\,(-n+cn+1)}{(c-1)\,(n(2c-1)+2)} \tag{12}$$

A necessary condition for this to hold is that the interval is defined, i.e.

$$\begin{aligned} n - \frac{2\,(cn+1)\,(-n+cn+1)}{(c-1)\,(n(2c-1)+2)} &> 0 \Rightarrow \\ \frac{-(n^2(c-1)+2(1+cn))}{(c-1)\,(n(2c-1)+2)} &> 0 \end{aligned}$$

which clearly cannot hold since $(n^2(c-1)+2(1+cn)) > 0$ and $(c-1)\,(n(2c-1)+2) > 0$ since $c > 1$.

Hence we see that (12) cannot be satisfied. This means that by selling licences to k firms, while the remaining $n-k$ firms are still active in the market, leads to a reduction in the total profit of the insiders. Hence, we have the following result:

Proposition 2 *There is no feasible licensing agreement involving the transfer of the superior technology to k firms given that the $n-k$ firms are active.*

2.1.3 Licensing with foreclosure

Allowing non-license takers to remain active is a drain on the profits of the insider group. Assume then that k is set so that $y^* = 0$, i.e.

$$n > k \geq \frac{1}{c-1} \tag{13}$$

Note that there are now only $k+1$ players in total (0 and the k licensees). This means that the expressions in (9) have to be adjusted accordingly by setting $y^* = 0$ and $n = k$ in x^* so that the amount of investment in the pure strategy Nash equilibrium is:

$$x^f = \frac{k}{(1+k)^2} V$$

with expected total payoffs to the group of $k+1$ insiders

$$\Pi^f = \frac{V}{k+1} \tag{14}$$

with each insider earning $\pi^f = \frac{V}{(k+1)^2} - t$ and firm 0 earning $\pi_0^f = \frac{V}{(k+1)^2} + tk$. Given that (13) is fulfilled, trade of licenses either at a positive or negative price is now feasible if total payoffs to the insiders (Firm 0 and the k licensees) are higher with than without license transfer:

$$\Delta\Pi = \Pi^f - \left(\widehat{\pi}_0^* + k\widehat{\pi}_j^*\right) \geq 0 \tag{15}$$

Feasibility of trade in licenses at a positive price requires that $\pi^f > \widehat{\pi}_j^*$ for each of the k insider firms, which is always satisfied since $cn > k$.

Given that $\Delta\Pi \geq 0$, firm 0 will choose the number of licenses, k, to make Π^f as large as possible in relation to the outside option of the licensees $(k\widehat{\pi}_j^*)$. This would imply that the total value added of licensing with foreclosure is maximised. Without any restrictions on the price structure or price level, a transfer payment between the licensees and the licensor can be set up to allow the licensor to capture the value added. Hence, firm 0 sets k that maximizes the following

$$\Pi_0^f = \Pi^f - k\widehat{\pi}_j^* = \frac{V}{(k+1)} - k\frac{V}{(cn+1)^2} \tag{16}$$

Since Π_0^f is decreasing in k, the lowest value of this parameter will be chosen, given that the foreclosure condition in (13) holds. Hence, firm 0 will set $k^f = \frac{1}{c-1}$ to achieve foreclosure of the $n-k$ firms. Inserting k^f into (15), trade is feasible, $(\Delta\Pi \geq 0)$, as long as

$$n^2c(c-1)^2 + 1 - 2c > 0 \tag{17}$$

We need also that $n > k^f = \frac{1}{c-1}$. It is easily verified that this is true when (17) is satisfied. From (17) we see that trades are more likely to be feasible the larger is n. Solving (17) delineates feasible trades, and we define n^f as the critical level of n that ensures feasible trades:

$$n > n^f = \sqrt{\frac{2c-1}{c(c-1)^2}} \tag{18}$$

Consequently, the larger is the number of potential firms, n, the more likely is the feasibility of trade in licenses. It is straightforward to show that the critical level of n^f is lower the higher is the marginal cost of effort for the outsiders, since $\partial n^f/\partial c < 0$ for $c \in (1,2]$

$$\frac{\partial n^f}{\partial c} = -\frac{(4c^2 - 3c + 1)}{2c^2(c-1)^3\sqrt{\frac{2c-1}{c(c-1)^2}}} < 0$$

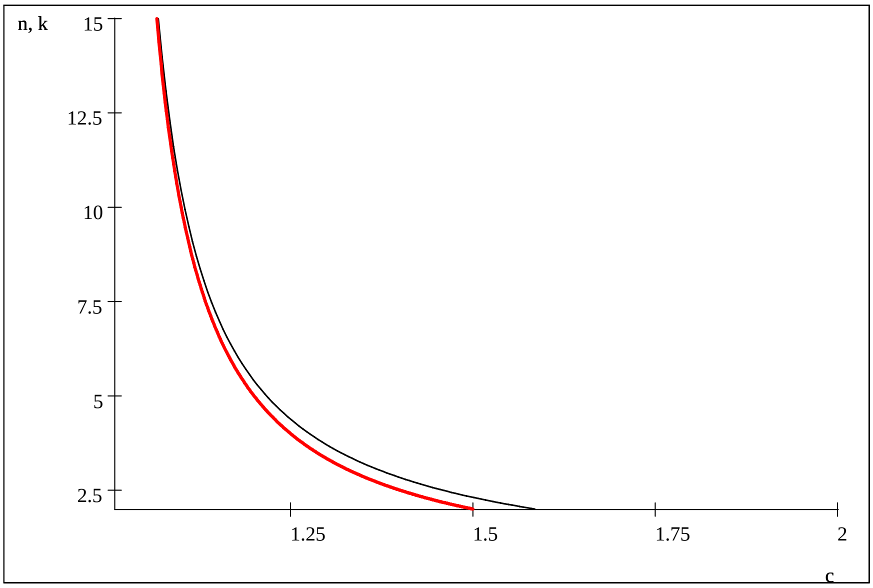

Figure: Foreclosure level k^f and the feasibility requirement n^f: n^f (thin line), k^f (thick line) for $n \geq 2$

For the sake of the argument, we concentrate on $n \geq 2$, so that at least one firm will be foreclosed. When c approaches 2, n^f approaches $\frac{1}{2}\sqrt{6} < 2$, such that trades will always be feasible. From (18) we find that $n^f = 2$ if $c \approx 1.59$. Consequently, if $c \in (1.59, 2]$, trade is feasible for all $n \geq 2$. In contrast, when c approaches 1, trades will not be feasible.

We thus state the following result:

Proposition 3 *Licensing to k firms in order to foreclose the $n - k$ firms from the market increases the total expected payoffs to the insiders as long as $n > n^f$, where n^f is decreasing in c.*

While trades are feasible when (15) is fulfilled, the condition that ensures that trade increases welfare is given by

$$\Delta W = \Pi^f - \left(\widehat{\pi}_0^* + n\widehat{\pi}_j^*\right) \geq 0 \tag{19}$$

Since $n > k$, as long as $n > n^f$, it follows that $\Delta W \geq 0$ is a stronger condition than $\Delta\Pi \geq 0$. Thus, the set of outcomes that involves feasibility of licensing is larger than the set of outcomes that is socially desirable. We insert for k^f into (14), and total expected payoffs to the insiders in the foreclosure case becomes:

$$\Pi^f(k^f) = \frac{V(c-1)}{c}$$

The condition that ensures that foreclosure increases welfare (19) may then be rewritten as

$$\Delta W = \frac{V(c-1)}{c} - \left(\frac{V(n^2(c^2-2c+1)+n(2c-1)+1)}{(cn+1)^2}\right) = \frac{V(c^2n^2-cn^2-cn-1)}{(cn+1)^2 c} \geq 0$$

It is easily verified that ΔW is an increasing function of n. Hence we can define n^w as the critical level of n that ensures that welfare increases:

$$n^w \equiv \frac{1}{2c(c-1)}\left(c + \sqrt{c(5c-4)}\right)$$

with welfare increasing for $n > n^w$.

Comparing the two critical levels of n, n^f and n^w, we first of all observe that n^w is strictly larger than n^f for all permissible parameter values. This implies that there are combinations of (n, c) such that license trading is feasible (with $n > n^f$), but where such trade is detrimental to welfare (with $n < n^w$). This is the area between the solid and dashed line in the figure below. As we observe from the figure, the area exists albeit not for a substantial set of parameter values. For most of the combinations of the parameters (n, c), feasible trade would also be welfare enhancing.

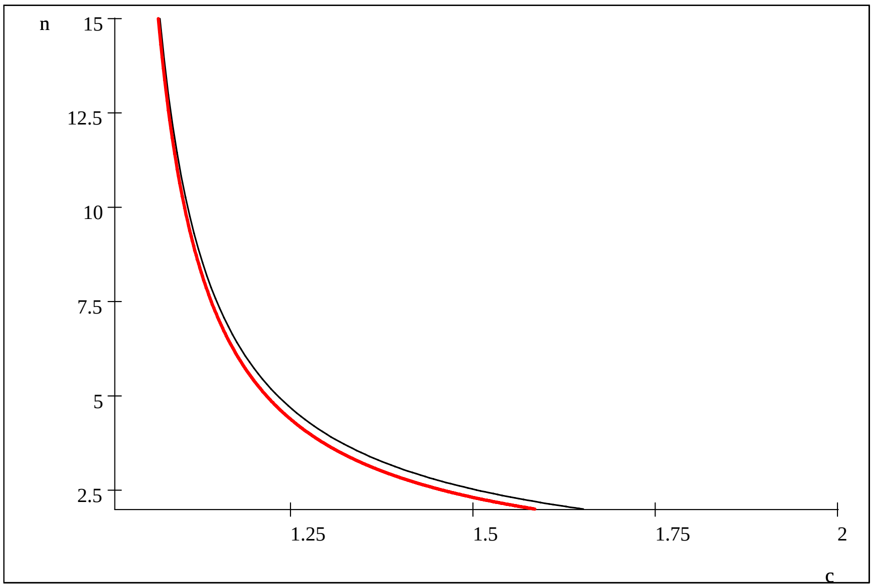

Figure: Feasible versus welfare enhancing trade (n^w thin line, n^f thick line), $n \geq 2$

We also need to check that $n > k^f \equiv \frac{1}{c-1}$, or since $n^w > n^f$ that $n > \max\left\{k^f, n^f\right\}$ which is trivially satisfied for $c > 1$:

$$\begin{aligned} n^f - k^f &= \sqrt{\frac{2c-1}{c(c-1)^2}} - \frac{1}{c-1} \\ &= \frac{1}{(c-1)}\left(\sqrt{\frac{2c-1}{c}} - 1\right) > 0 \text{ for } c \in (1,2] \end{aligned}$$

It is straightforward to show $\partial \Delta W / \partial c > 0$ and $\partial \Delta W / \partial n > 0$ for $c \in (1,2]$. Hence welfare will increase most the more disadvantaged the rivals to 0, and the larger their initial number. Moreover, we have that $\Delta W > 0$ when c approaches 2, while $\Delta W < 0$ when c approaches 1.

3 Licensing of inferior technologies

To check the robustness of the results of the previous section, we now consider whether firm 0 may benefit from transferring technology that is better than rivals have at the outset but that is not as efficient as the one used by firm 0. One may interpret this as transferring a technology of an intermediate quality, where quality becomes a choice variable for firm 0. Let us assume that k firms are allowed to acquire the technology a, where $a \in [1, c]$, and $n-k$ still have the technology c. The first-order conditions are now given by:

$$\begin{aligned}
\frac{\partial \pi_0}{\partial x_0} &= \frac{\left(\sum_{s\in T} x_s + \sum_{v\in NT} x_v\right) V}{\left(x_0 + \sum_{s\in T} x_s + \sum_{v\in NT} x_v\right)^2} - 1 = 0 \\
\frac{\partial \pi_j}{\partial x_j} &= \frac{\left(x_0 + \sum_{s\neq j\in T} x_s + \sum_{v\in NT} x_v\right) V}{\left(x_0 + \sum_{s\in T} x_s + \sum_{v\in NT} x_v\right)^2} - a = 0,\ j \in T \\
\frac{\partial \pi_i}{\partial x_i} &= \frac{\left(x_0 + \sum_{s\in T} x_s + \sum_{v\neq i\in NT} x_v\right) V}{\left(x_0 + \sum_{s\in T} x_s + \sum_{v\in NT} x_v\right)^2} - c = 0,\ i \in NT
\end{aligned} \tag{20}$$

Then we have the following equilibrium investments for each firm type (0, T, NT):

$$\begin{aligned}
x_0(a) &= \frac{(cn - ck - n + ka + 1)\, Vn}{(cn - ck + ka + 1)^2} \\
x_T(a) &= \frac{(cn - ck + ka - na + 1)\, Vn}{(cn - ck + ka + 1)^2} \\
x_{NT}(a) &= \frac{(k\,(a-c) + 1)\, Vn}{(cn - ck + ka + 1)^2}
\end{aligned} \tag{21}$$

From x_{NT} we have that if $k \geq \frac{1}{c-a}$, then $n-k$ are driven out of the market. Bearing in mind that outsiders just drain resources away from firm 0 and its potential customers, let us assume that this is the case, so that the investment levels in (21) have to be rewritten for the fact that the number of competitors to firm 0 is $k = n$. Hence equilibrium investments are

$$\begin{aligned}
x_0^f(a) &= \frac{(1 + k(a-1))\, k}{(1+ka)^2} V \\
x_T^f(a) &= \frac{k}{(1+ka)^2} V
\end{aligned}$$

with corresponding expected payoffs:

$$\begin{aligned}\pi_0^f(a) &= V\frac{(k(a-1)+1)^2}{(ka+1)^2} \\ \pi_T^f(a) &= V\frac{k(a-1)+1}{(ka+1)^2}\end{aligned}$$

Aggregate payoffs of active firms is then

$$\Pi^f(a) = \pi_0^f(a) + k\pi_T^f(a) = V\frac{k(a-1)+1}{ka+1}$$

which is strictly increasing in a and strictly decreasing in k. The maximum that firm 0 can increase its payoff compared to the outset will be the excess of aggregate payoffs over the k insiders' outside options given by $\frac{V}{(cn+1)^2}$ (from (3)). Then, firm 0 maximizes $\Pi_0^f(a) = \Pi^f(a) - k\frac{V}{(cn+1)^2}$ by choice of k and a. The level of k will be set as low as possible, or a as large as possible. However $a = c$ does not represent a transfer of technology so we consider setting k at the lowest level commensurate with foreclosure: denote this by $k^f(a) = \frac{1}{c-a}$. Inserting $k^f(a)$ into $\Pi^f(a)$ gives

$$\Pi^f(k^f(a)) = \frac{V(c-1)}{c}$$

where $\pi_0^f(k^f(a)) = \frac{V(c-1)^2}{c^2}$ and $\pi_T^f(k^f(a)) = \frac{V(c-1)(c-a)}{c^2}$

Total expected payoffs of the insiders $\Pi^f(k^f(a))$ are independent of a. Thus, one has the policy implication that, as long as trades are feasible, welfare is independent of the level of $a \in [1, c)$, i.e. the quality of the transferred technology does not affect total welfare. However, from $\Pi_0^f(a) = \frac{V(c-1)}{c} - k\frac{V}{(cn+1)^2}$ we see that firm 0 prefers to set $a = 1$ since $k^f(a > 1) > k^f(a = 1)$.

Proposition 4 *Firm 0 will set a as low as possible such that $a = 1$, giving $k = \frac{1}{c-1}$. The outcome is identical to Proposition 3, and trades will be feasible as long as $n > n^f$ is satisfied.*

The dominant firm faces a trade off in its choice of technology quality to transfer to rivals. Better quality means stronger competition from firms that have the new technology, but at the same time it allows foreclosure of more of the rival firms. The latter effect dominates here.

4 Concluding remarks

This paper has analysed a situation in which a dominant technological leader competes with rivals for shares of a market of fixed size. The dominant firm derives increased profits from being technologically superior, and if it can force some rivals out of the market. We consider the interconnection between these forces by allowing the technology to be licensed to some rivals in order to foreclose others. Due to the fixed size of the market, some degree of foreclosure is necessary to make license payments feasible. Selective or exclusive licensing is an accepted mode of transferring intellectual property rights between firms as outlined by the US Department of Justice and the Federal Trade Commission in the *Antitrust Guidelines for Licensing Intellectual Property* from 1995.[5] Hence some degree of foreclosure will not be ruled out a priori by law.

On the other hand, to the extent that the transferred technology guarantees access to an essential input, competition authorities may adopt a policy of no discrimination. Under the competition laws in the United States and the EU the essential-facilities doctrine may apply towards dominating firms which control a bottleneck, and a dominating firm may be obligated to provide access to rivals at non-discriminatory terms (see e.g. Bergman, 2001). Moreover, in regulated industries like telecommunications, obligations which require that the incumbent provides access at non-discriminatory terms are part of the current regulatory regimes both in the United States and the EU. If such non-discriminatory obligations are present, welfare-enhancing licensing of technology may be precluded.

We have also considered the possibility that the dominant firm can choose to license an inferior version of its technology to rivals, and we have found that the total profit of the active firms will be independent of the quality of the licensed technology. However, the desire to foreclose as many rivals as possible is so strong that the dominant firm chooses to transfer the best quality of technology to as few competitors as possible, given the restrictions on the feasibility of trade (i.e. that trade benefits both buyer and seller).

[5] See the discussion in Scotchmer (2004), chapter 6.

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