On the licensing of a demand-enhancing innovation

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Abstract

In this paper we analyze the licensing of an innovation that raises the quality level of the products in a market and also expands total market demand. We show that if consumers' evaluation for the products is sufficiently high then irrespective of the magnitude of the innovation there is no transfer of technology from an incumbent innovator to his rival. If the evaluation is low then transfer of technology occurs only if the magnitude of the innovation is sufficiently low.

Keywords: quality-improving innovation; demand expansion; incumbent innovator; transfer of technology

JEL: D43, D45, L13

1 Introduction

Most of the literature on patent licensing is devoted to process innovations and has neglected, at a large extend, innovations that expand market demand. As a mater of fact though for a large number of industries a significant proportion of firms' research effort is devoted to introduction of innovations that affect directly market demand (see Mansfield (1983), Petsas & Gannikos (2005)). Hence the study of licensing of demand-expanding innovations seems of practical importance.

This paper deals with the licensing of such an innovation. We utilize a Hotelling duopoly model where besides the usual horizontal differentiation consumers are also

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differentiated in terms of their evaluation for quality. We assume that one of the two firms introduces an innovation that raises quality. This induces an expansion of the consumer set. We examine whether transfer of technology takes place between the innovator and his rival. It is shown that if the valuation for the products is sufficiently high then irrespective of the magnitude of the innovation neither the non-innovating firm nor the innovator are interested in the transfer of the new technology. If the evaluation is low then for sufficiently small innovation sizes both the innovator and his rival benefit from the transfer of technology. Licensing in this case occurs even if we restrict attention to an up-front fee policy (as we do in this paper).

In what follows we present the model and main assumptions in section 2.1. We then determine price equilibria, first in the case where only the innovator uses the new technology and afterwards when both firms produce utilizing the new technology. In the last part we determine the conditions under which the non-innovating firm is willing to acquire the new technology and those under which the innovator is interested in licensing it. In the last part we conclude.

2 The model

We consider a Hotelling duopoly where firm 1 is located at point 0 and firm 2 at point 1 of the interval $[0, 1]$. Firm i produces a product of quality $s_i, i = 1, 2$. The marginal cost of production is $c > 0$, common to both firms. Fixed cost is zero. Given locations and qualities (both fixed) firms compete in prices.

The demand side consists of two sets of consumers, $\mathcal{N}$ and $\mathcal{F}$. Consumers of the first set are uniformly distributed in $[0, 1]$. The evaluation of consumer $x \in \mathcal{N}$ for the product of firm 1 is given by $u_1(x) = v - x + \theta s_1 - p_1$ where θ the marginal evaluation of quality (fixed for all members of $\mathcal{N}$), p_1 the price of the product and $v > 0$. His evaluation for the product of firm 2 is given $u_2(x) = v - (1 - x) + \theta s_2 - p_2$ where p_2 the price of the product.

The members of $\mathcal{F}$ are uniformly distributed in $[a, b] \subseteq [0, 1]$. These consumers differ from the members of $\mathcal{N}$ in that they purchase a product only if its quality is above a threshold; otherwise they stay out of the market. We let this quality threshold be 0 (common to all members of $\mathcal{F}$). We assume that the evaluation of a member of $\mathcal{F}$ located at $z \in [a,b]$ for the product of firm 1 and 2 respectively is

$$u_1(z) = \begin{cases} v - z - p_1 + A(s_1), & \text{if } s_1 > 0 \\ 0, & \text{if } s_1 = 0 \end{cases}$$

and

$$u_2(z) = \begin{cases} v - (1-z) - p_2 + A(s_2), & \text{if } s_2 > 0 \\ 0, & \text{if } s_2 = 0 \end{cases}$$

The function $A(s_i)$ denotes the (common) evaluation for quality of consumers in $\mathcal{F}$ (its form will be specified later). When the quality level is not above the threshold all consumers in $\mathcal{F}$ stay out of the market. We assume that $a = 1 - b$. This says that consumers in $\mathcal{F}$ are symmetrically distributed around $\frac{1}{2}$. We finally assume that prior to any innovation activity the quality levels of the two products are $s_1 = s_2 = 0$; hence all consumers in $\mathcal{F}$ are out of the market and we are in a typical Hotelling model.

2.1 Demand-expanding innovation

Let now one of the two firms (firm 1) innovate a higher quality which is $s_1 = s > 0$. The demand size changes as members of $\mathcal{F}$ are now willing to enter the market[1]. If the innovating firm is the exclusive user of the new technology she operates as a monopoly over $\mathcal{F}$; if she licenses to her rival the two firms compete over this set of consumers. In what follows we analyze the behavior of the two firms with regard to technology transfer and pricing. The interaction unfolds via the following 3-stage game: in the first stage the innovator decides whether to license or not the new technology. We restrict attention to up-front fee policies only; in the second, firm 2 decides whether to accept or not any offered contract; finally, in the third stage firms compete in prices. If licensing takes place the corresponding game is denoted by G_T. If no licensing occurs it is denoted by G_0. We assume that when $s > 0$,

$$A(s) = \theta_1 s, \qquad \theta_1 > \frac{5}{2}\theta \qquad (A1)$$

$$v > a + c \qquad (A2)$$

[1]Using the interpretation that $[0,1]$ expresses the set of possible values of a characteristic of the products then the total mass of consumers whose ideal value of the characteristic lies in $[a,b]$ is $2[a,b]$

2.1.1 The G_0 game

We begin the analysis by first deriving the demand functions of the two firms in G_0. Consider first $\mathcal{F}$ over which firm 1 acts as a monopolist. Let x_1^f denote the furthest (from firm 1) member of $\mathcal{F}$ purchasing the product of firm 1. Then $x_1^f = v + \theta_1 s - p_1$ and hence the demand function, d_1^f, of firm 1 that corresponds to $\mathcal{F}$ is $d_1^f = x_1^f - a$. Let next d_1^n and d_2^n denote the demand shares of the two firms in $\mathcal{N}$. Then

$$d_1^n = \begin{cases} v+\theta_1 s-p_1-a, & \text{if } p_1 > p_2+1+\theta s \\ \frac{p_2-3p_1+1+\theta s}{2}+v+\theta_1 s-a, & \text{if } p_2-1+\theta s < p_1 < p_2+1+\theta s \\ 1+v+\theta_1 s-p_1-a, & \text{if } p_1 \leq p_2-1+\theta s \end{cases}$$

$$d_2^n = \begin{cases} 0, & \text{if } p_2 > p_1+1-\theta s \\ \frac{p_1-p_2+1-\theta s}{2}, & \text{if } p_1-1-\theta s < p_2 < p_1+1-\theta s \\ 1, & \text{if } p_2 \leq p_1-1-\theta s \end{cases}$$

The best-reply correspondences are

$$\mathcal{BR}_1 = \begin{cases} \frac{v+\theta_1 s-a+c}{2}, & \text{if } p_2 < p_{2D} \\ \frac{p_2}{6}+\frac{2\theta_1 s+1+\theta s 2v-2a+3c}{6}, & \text{if } p_{2A} < p_2 < p_{2B} \\ p_2+\theta s-1, & \text{if } max\{p_{2B}, p_{2D}\} \leq p_2 \leq p_{2G} \\ \frac{1+v+\theta_1 s-a+c}{2}, & \text{if } p_2 \geq p_{2G} \end{cases}$$

$$\mathcal{BR}_2 = \begin{cases} p_1-1-\theta s, & \text{if } p_1 > p_{1G} \\ \frac{p_1+1+c-\theta s}{2}, & \text{if } p_{1A} < p_1 < p_{1G} \\ p_1+1-\theta s, & \text{if } p_1 \leq p_{1A} \end{cases}$$

The values of the thresholds on prices are given in the Appendix. Three types of equilibrium could exist in G_0; one where firm 1 sells to $\mathcal{F}$ only, one where firm 1 sells to both groups while firm 2 stays in the market for $\mathcal{N}$ and a last one where firm 1 sells to both groups and firm 2 exits. We denote the prices prevailing in the first and second type of equilibrium by $p^* = (p_1^*, p_2^*)$ and $p^{nf} = (p_1^{nf}, p_2^{nf})$ respectively. In the first type of equilibrium all of $\mathcal{N}$ is covered if $v - 1 - p_2^* \geq 0$ which holds if $s \leq s_u = \frac{v+a-c}{\theta_1 - 2\theta}$ (which is always positive). In the second type $\mathcal{N}$ is covered if $v - d_{2n} - p_2^{nf} \geq 0$ (or equivalently if $v + \theta s - d_{1n} - p_1^{nf} \geq 0$) which holds iff $s \leq s_z = \frac{16v+6a-21-16c}{3(2\theta_1-5\theta)}$. Notice that $s_z > 0$ iff $v > v_z(a,c) = \frac{21-6a}{16} + c$.

Lemma 1. *Consider G_0 and let $v > v_z(a,c)$. There exist functions $v_n(a,c)$, $v_p(a,c)$ and s_n, s_p, s_z such that the following hold.*
(i) if $v > v_n(a,c)$ then for all $s < s^u$ the unique price equilibrium is p^*
(ii) if $v_p(a,c) < v < v_n(a,c)$ and $s < s_u$ the game has two equilibria, p^{nf} and p^*; and if $s_u < s < s_z$ the unique equilibrium is p^{nf}
(iii) if $v_c(a,c) < v < v_p(a,c)$ and $s \in [s_p, s_u]$ G_0 has two equilibria, p^{nf} and p^*; if $s_u < s < s_z$ the unique equilibrium is p^{nf}
(iv) if $v_z(a,c) < v < v_c(a,c)$ and $s < s_n$ the unique equilibrium is p^{nf}

The values of s_n, s_p, etc, depend on v, a, θ, c and θ_1 and are all given in the Appendix.

2.1.2 The G_T game

Consider the market interaction where both firms operate with the new technology. We assume that transfer of technology occurs via an up-front fee policy (with zero royalty). The demand function of firm 1 is

$$d_1 = \begin{cases} 0, & \text{if } p_1 \geq p_2 + 1 \\ \frac{p_2 - p_1 + 1}{2}, & \text{if } p_2 + 1 - 2a \leq p_1 < p_2 + 1 \\ p_2 - p_1 + 1 - a, & \text{if } p_2 - 1 + 2a \leq p_1 < p_2 + 1 - 2a \\ 1 - 2a + \frac{p_2 - p_1 + 1}{2}, & \text{if } p_2 - 1 \leq p_1 < p_2 - 1 + 2a \\ 2 - 2a, & \text{if } p_1 < p_2 - 1 \end{cases}$$

and similarly for firm 2.

Lemma 2. *Consider G_T and let $c > 1 + a$. There exists a_1 such that the following hold*
(i) if $a < a_1$ the unique equilibrium is given by $p_1^* = p_2^* = 1 + c - a$
(ii) if $a_1 \geq a$ there are two equilibria, (p_1^*, p_2^*) and $(p_i^{**}, p_j^{**}) = (-1 + c + 4a, 2a + c)$

The equilibrium (p_i^{**}, p_j^{**}) is unique up to a permutation of the names of the firms.

2.1.3 Comparison of the two games

We now compare the payoffs each of the firms obtains in each of the two games. We assume that in G_T the equilibrium selected is the symmetric one while we allow both equilibria in G_0 to occur. We start with firm 2.

Lemma 3. *Consider G_T. There exists a function $v_f(a, c)$ and constants a_0,a_2 such that the following hold.*
(i) if the equilibrium in G_0 is (p_1^*, p_2^*) firm 2 never accepts to acquire the new technology
(ii) if the equilibrium in G_0 is (p_1^{nf}, p_2^{nf}) and $a > a_0$ firm 2 never accepts to acquire the new technology.
(iii) if the equilibrium in G_0 is (p_1^{nf}, p_2^{nf}) and $a < a_0$ firm 2 is willing to acquire the new technology in the following cases:
$(iii_{(a)})$ $a_2 < a < a_0$: *if* $v \in [v_z, v_f]$ *and* $s < s_n$
$(iii_{(b)})$ $a_2 > a$: *if* $v \in [v_c, v_f]$ *and* $s < s_z$ *or if* $v \in [v_z, v_c]$ *and* $s < s_n$

Hence if v is large irrespective of the magnitude of the innovation firm 2 is hurt by acquiring the new technology even if she gets it for free. So in this case no technology transfer ever takes place. Finally given the parameter range under which firm 2 prefers to become licensee we examine under what conditions firm 1 prefers too to transfer the technology. We restrict attention to up-front fee policies.

Proposition 1. *Consider G_T. There exist functions $v_t(a, c)$ and s_t and a constant a_3 such that firm 1 licenses the new technology to firm 2 via an up-front fee policy if $a < a_3$, $v_z(a, c) < v < v_t(a, c)$ and $s < min\{s_n, s_t\}$.*

Whenever v is sufficiently large firm 1 finds it optimal not to transfer the technology to her rival, irrespective of the magnitude of the innovation. If the evaluation is high both firms prefer the outcome where firm 1 acts as a monopolist over $\mathcal{F}$ as then firm 1 can set high price and extract high revenue from the members of $\mathcal{F}$; that in turn allows firm 2 to also set a high price (due to price complementarity).

3 Conclusions

In this note we have developed a model to analyze the licensing of a demand-expanding innovation. The model is characterized by the heterogeneity of consumers with regard to quality. We have shown that when the evaluation for the products is sufficiently high neither the (incumbent) innovator nor his opponent are interested in the transfer of technology. When the evaluation is low enough then small innovations do get licensed even if we restrict attention to up-front fee policies only. It is interested to note one similarity and one difference with a cost-reducing innovation. Poddar & Sinha (2004) analyzed a cost-reducing innovation in a linear city framework (with fixed demand size). They show that a incumbent innovator licenses his innovation to his rival whenever the innovation is not drastic. This happens in our model too but only if the evaluation is low.

Appendix

Proof of Lemma 1. Consider first the possibility of an equilibrium where firm 1 monopolizes both markets. If such an equilibrium outcome exists it must be (by examining the best-reply correspondences) that either $(p_1^{**}, p_2^{**}) = (\frac{1+v+\theta_1 s-a+c}{2}, c)$ (if $c > p_{2G}$ and $p_1^{**} < p_{1A}$) or $(p_1^c, p_2^c) = (c+\theta s-1, c)$ (if $max\{p_{2B}, p_{2D}\} < c < p_{2G}$ and $p_1^c < p_{1A}$). The condition $p_1^{**} < p_{1A}$ does not hold. Likewise the condition $c > max\{p_{2B}, p_{2D}\}$ cannot hold, where $p_{2G} = \frac{3+v-a+c+(\theta_1-2\theta)s}{2}$, $p_{2B} = \frac{2v+(2\theta_1-5\theta)s+7-2a+3c}{5}$, $p_{2D} = \frac{v+(\theta_1-2\theta)s-a+c-2}{2}$ and $p_{1A} = \theta s - 1 + c$.

Consider the possibility of an equilibrium where firm 1 sells only to $\mathcal{F}$. The candidate pair of prices is $(p_1^*, p_2^*) = (\frac{v+\theta_1 s-a+c}{2}, \frac{v+(\theta_1-2\theta)s-a+c-2}{2})$; the condition required is $p_1^* > p_{1G}$ which is met iff $s > s_p \equiv \frac{-v+a+c+6}{\theta_1-2\theta}$. Hence if $v > v_p = a+c+6$ this equilibrium always exists.

Consider next the possibility where firm 1 sells to both groups while firm 2 stays in the market. If such an equilibrium outcome exists we have $(p_1^{nf}, p_2^{nf}) = (\frac{4(v+\theta_1 s+c-a)+3(1+c)+\theta s}{11}, \frac{2(v+c-a)+(2\theta_1-5\theta)s+7(1+c)}{11})$. The condition needed is $s_m < s < s_n$ where $s_m = \frac{-2v+2c+2a-7}{2\theta_1-5\theta}$ (which is negative) and $s_n = \frac{-2v+2c+2a+15}{\theta_1-5\theta}$. Hence if $v > v_n = c+a+\frac{15}{2}$ such an equilibrium does not exist. Note further that for all $v < v_n$ we have $s_n > s_p$; hence if $s \in [s_p, s_n]$ and $v < v_n$ the game has two equilibria.

For $\mathcal{N}$ to be covered when both firms are active in $\mathcal{N}$ we need $s < s_z$ where $s_z > 0$ iff $v > v_z = \frac{21-6a}{16}+c$. Using also the condition $s < s_n$ which can hold only if $v < v_n = c+a+\frac{15}{2}$ we need $v_z < v < v_n$. Moreover $min\{s_z, s_n\} = s_z$ iff $v \in [v_c, v_n]$ where $v_c = 3+c$. To summarize (p_1^{nf}, p_2^{nf}) is equilibrium if $v \in [v_z, v_n]$ and $s < s_n$ if $v \in [v_z, v_c]$ and $s < s_z$ if $v \in [v_c, v_n]$.

Consider next the case where only firm 1 is active in $\mathcal{N}$. In order for firm 2 to sell to all of $\mathcal{N}$ we need $s < s_u = \frac{v+a-c}{\theta_1-2\theta}$; If $v > v_p(a,c)$ then for all $s \leq s_u$, (p_1^*, p_2^*) is equilibrium; if $c+3 < v < v_p(a,c)$ then it is equilibrium if $s \in [s_p, s_u]$; if $v < c+3$ then it is not equilibrium as $s_p > s_u$. ∎

Proof of Lemma 2. The best reply correspondence of firm 1 when $c > 1+a$ is

$$\mathcal{BR}_1 = \begin{cases} p_2-1, & \text{if } p_2 \geq 5-4a+c \\ \frac{p_2+3+c-4a}{2}, & \text{if } 5-8a+c \leq p_2 < 5-4a+c \\ p_2-1+2a, & \text{if } max\{3-5a+c, -1+c+4a\} \leq p_2 < 5-8a+c \\ \frac{p_2+1-a+c}{2}, & \text{if } -1+c+3a \leq p_2 < 3-5a+c \\ \frac{p_2+1+c}{2}, & \text{if } -1+c < p_2 < -1+c+4a \\ p_2+1-2a, & \text{if } p_2 \leq -1+c \end{cases}$$

Similarly we can construct the best-reply correspondence of firm 2. Consider as candidate equilibrium the prices where both firms sell to both groups; they satisfy $p_1 = \frac{p_2+1-a+c}{2}$, $p_2 = \frac{p_1+1-a+c}{2}$ and $p_1^{**} = p_2^{**} = 1-a+c$; the conditions needed are $-1+c+3a < p_i^{**} < 3-5a+c$ which always hold.

Consider next the possibility where one of the two firms (say firm 1) sells to all of $\mathcal{N}$ and the other sells to all of $\mathcal{F}$: this requires $p_1 < p_2-1$ and $p_1 > p_2+1-2a$ which cannot both hold as $a \leq \frac{1}{2}$. Next we analyze the case where one of the firms (firm 1) sells to all of $\mathcal{F}$ while she shares $\mathcal{N}$ with her opponent. This can happen in two occasions. In the first prices solve $p_1 = \frac{p_2+3+c-4a}{2}$ and $p_2 = \frac{p_1+1+c}{2}$ where $5-8a+c \leq p_2 < 5-4a+c$ and $-1+c \leq p_1 \leq -1+c+4a$; however the solution of the two equations do not satisfy the two last conditions. In the second case prices satisfy $p_1 = p_2-1+2a$ and $p_2 = \frac{p_1+1+c}{2}$; the solution is $p_1^{**} = -1+c+4a$, $p_2^{**} = 2a+c$; the conditions needed are: (i) $a < \frac{4}{9}$:

$3-5a+c \leq p_2 \leq 5-8a+c$ and $-1+c \leq p_1 \leq -1+c+4a$; the condition $-1+c \leq p_1^{**} \leq -1+c+4a$ is always satisfied while the condition $3-5a+c \leq p_2^{**} \leq 5-8a+c$ holds if $a_1 \equiv \frac{3}{7} \leq a$; (ii) $a \geq \frac{4}{9}$: $-1+c+4a \leq p_2 \leq 5-8a+c$ and $-1+c \leq p_1 \leq -1+c+4a$ which hold. The case where one of the firms monopolizes $\mathcal{N}$ and shares $\mathcal{F}$ cannot occur as monopolization of $\mathcal{N}$ implies monopolization of $\mathcal{F}$ as well.

Proof of Lemma 3. We compare the payoff of firm 2 in G_0 and in G_T. Consider first the case where the equilibrium in G_0 is (p_1^*, p_2^*). In this case firm 2 is willing to pay a positive fee for the new technology iff $s < s_1 = \frac{-v+4-3a+2a^2+c}{\theta_1-2\theta}$; $s_1 > 0$ if $v < v_1 = c+4-3a+2a^2$ where $v_c < v_1 < v_p$. Hence we are in the case where $s \in [s_p, s_u]$; however $s_1 < s_p$. Hence there is no transfer of technology when the equilibrium in G_0 is (p_1^*, p_2^*).

Consider next the (p_1^{nf}, p_2^{nf}) equilibrium. The fee is $\Phi = (1-a)^2 - \pi_2^{nf}$ and is positive iff $s < s_f = \frac{-2(v-c-a)-7-11\sqrt{2}(-1+a)}{2\theta_1-5\theta}$; note that $s_f > 0$ iff $v < v_f = c+a-\frac{7}{2}+11\frac{\sqrt{2}}{2}(1-a)$. We first note that if $a > 0.46$ then $v_f < v_z$. So let $a < 0.46 = a_0$. Note that $v_z < v_c < v_f < v_p$ if $a < a_2 = 0.18$ and $v_z < v_f < v_c < v_p$ if $a > 0.18$. Consider the case $a > a_2$: the fee is positive if $v \in [v_z, v_f]$ and if $s < min\{s_n, s_f\} = s_n$. Consider next the case $a < a_2$: if $v \in [v_c, v_f]$ the fee is positive if $s < min\{s_z, s_f\} = s_z$; if $v \in [v_z, v_c]$ the fee is positive is $s < min\{s_n, s_f\} = s_n$. ■

Proof of Proposition 1. We compare the payoff of firm 1 in G_0 and in G_T when $a < a_0$. We only need to consider the case where the equilibrium in G_0 is (p_1^{nf}, p_2^{nf}). The total payoff from licensing is $T = 2(1-a)^2 - \pi_2^{nf}$ and $T \geq \pi_1^{nf}$ iff $s < s_t$ where $s_t = \frac{11\sqrt{K}-25\theta_1+13\theta-(v-a-c)(26\theta_1+\theta)}{2(7\theta^2+13\theta_1+\theta_1\theta)}$ and K a function of $a, c, theta_1, theta, v$; note that $s_t > 0$ iff $v < v_t = c+a-\frac{25}{26}+\frac{11\sqrt{52a^2-104a+49}}{26}$; note that if $a > a_3 = 0.38$ them $v_t < v_z$; in this case licensing cannot occur. So let $a < a_3$. Note that $v_t < v_f < v_c$. Then licensing occurs if $v \in [v_z, v_t]$ and $s < min\{s_n, s_t\}$. ■

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