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Abstract

This paper studies how a separation of ownership and management affects a firm's incentives to transfer knowledge about technology to a rival in a Cournot duopoly. We consider a three-stage strategic delegation game, where there are two technologies available; one with increasing returns to scale and the other with constant returns to scale. Whilst the former is known to both firms, only the more advanced firm has initially access to the latter type of technology. This firm is assumed to be managerial, not only with respect to product market decisions, but also regarding the choice of whether or not to transfer technology to the rival firm. We show that strategic management will not necessarily affect the decision to transfer technology to a rival, but we identify conditions under which it changes the technology choice of the managerial firm. Welfare implications of this are considered.

Keywords: Technology transfer, managerial incentives, technology adoption.

JEL :O14, O30, L13

1 Introduction

Diffusion of technology can be regarded as a prerequisite for exploiting the full economic benefits of new discoveries. Baumol (2002), among others,

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regards innovation to be one of the main factors behind economic growth, stating that new technology is spread rapidly across economies, as it often pays innovators to share their knowledge, rather than to hoard it to themselves. One can dichotomize the literature on technology transfer according to whether or not access requires a payment. Transfer may be secured through licensing agreement of various kinds, or it may be accomplished free of charge to the recipient.¹ The latter is often puzzling for economists since voluntary transfer can be regarded as diminishing a comparative advantage. Harhoff et al. (2003) discuss the incentives for free-revelation, including the insignificance of licensing income, costs associated with protecting innovations, and the short timespan from invention to imitation. Inventions can also be made more robust by disseminating them to users before commercialization (Mishina, 1989), or peer recognition may be an important factor in the revelation decision (see for example Lockemann, 2004). Theoretical motives and the empirical relevance of the voluntary revelation of technological information is surveyed by Lhuillery (2006).

One recent novel approach to technology transfer is that of Bacchiega and Garella (2008) - henceforth BG - who study a firm's incentives to transfer knowledge about competing production technologies to a less knowledgeable rival in a Cournot duopoly. These technologies yield qualitatively different cost functions and change the incentives of the recipient firm in the product market. In this setting, the transfer of technology to a rival can actually yield a competitive advantage for the transferring firm. In this paper we extend the BG analysis to include managerial incentives on the part of the most technologically advanced firm. As an illustration, Eden et al (1997) maintain that multinational enterprises are the world's technology producers, and here any transfer decisions will be delegated away from the owners. We are interested in how the separation of ownership and control changes the incentives for technology transfer and its subsequent adoption. Importantly, it is not just the production decision that is delegated to the manager, but also the decision about whether or not technology should be transferred. This is different to the approach of Mukherjee (2001) who looks at a model of technology licensing with managerial delegation, but the only decision made by the manager is about production; the licensing decision is made by the owner before a manager is hired. Hence we consider the management of technology transfer as well as production decisions. In giving incentives to the manager, we employ a common objective function that is a weighted

¹For an analysis of the effects of licensing agreements on technology transfer in Cournot duopoly see Wang and Yang (2004).

average of firm profits and income.²

In extending the BG model, we retain the feature that there is initially no superior technology since one of these yields a cost function involving only fixed costs while the other has only variable costs. This is in contrast to much of the licensing literature which looks at incremental improvements to an existing technology through the transfer of new knowledge.³ We show that the incentives given by the owner of the most informed firm do not affect the frequency of technology transfer, but that it can have an effect on which technologies are employed by the transferring firm in equilibrium. We identify conditions under which the firm owner benefits from delegation. From a welfare point of view, we identify the technology choices that would be dictated by a social planner and compare this to the market equilibrium. Furthermore, we consider the setting of the incentive parameter by a social planner who aims at maximizing social welfare and not just profits. We identify conditions under which the firm owner actually takes socially optimal decisions.

The paper is organized as follows: In Section 2 we develop a model of strategic delegation with possible technology transfer to a rival in a Cournot duopoly. In Section 3 analysis of the equilibrium is presented. In Section 4 we look at welfare aspects of technology transfer, and in Section 5 we offer some concluding remarks.

2 The Model

Consider an industry with two firms, labeled 1 and 2, producing a homogeneous good. Inverse market demand is linear and it is equal to

$$p = 1 - Q \tag{1}$$

where $Q = q_1 + q_2$ and p denotes the market price. The cost function naturally depends on the technology adopted, where technology V is characterized by a constant positive unit cost $c > 0$, while technology K is characterized by only a fixed cost $F > 0$. Firm 1 can adopt one of two available technologies V or K . The cost function for firm 1, depending on the technology choice,

²This was introduced by Fershtman and Judd (1987) and Sklivas (1987), and utilised in the work of Mukherjee (2001). Recently, Jansen et al. (2007) have examined a market share version of delegation games, finding that this gives qualitatively similar results to basing incentives on profits and income/sales.

³Such as Wang and Yang (2004) and Mukherjee (2001).

will then be given by one of the following

$$\begin{aligned} c_1^V &= cq_1 \\ c_1^K &= F \end{aligned}$$

Initially, firm 2 only possesses technique K,⁴ and has cost

$$c_2^K = F$$

We consider a three-stage model of competition between two firms, depicted in Figure 1. At stage 1 the owner of firm 1 designs an incentive scheme for a manager, and this depends upon a weighted sum of firm 1's profit and revenue. Hence, we regard firms' profit and liquidity as important aims as in the seminal work by Fershtman and Judd (1987). The maximand for the manager is then

$$\begin{aligned} M_1 &= \alpha\pi_1(q_1, q_2) + (1 - \alpha) R_1(q_1, q_2) \\ &= R_1(q_1, q_2) - \alpha C(q_1) \end{aligned} \tag{2}$$

where π_1 and R_1 are firm 1's profit and revenue, $C(q_1)$ is the relevant cost function and $0 \leq \alpha \leq 1$. If $\alpha < 1$ firm 1's manager moves away from strict profit maximization. In this model we assume that firm 2 is entrepreneurial (a firm which is owner-managed). Hence the owner of firm 2 maximizes its profit.

At the second stage, the manager of firm 1 decides whether to transfer the knowledge of the second technique to firm 2; firm 2 observes this choice and conditional on the decision of firm 1, the firms make their technology choices. At stage 2, the manager of firm 1 has four possible actions:

- VH : firm 1 adopts technology V and does not transfer V to firm 2
- KH : firm 1 adopts technology K and does not transfer V to firm 2
- VT : firm 1 adopts technology V and transfers technology V to firm 2
- KT : firm 1 adopts technology K and transfers technology V to firm 2

If the manager of firm 1 does not transfer technology V , firm 2 must adopt the only technology at its disposition at stage 2 (technology K). If technology V is transferred, then the owner of firm 2 must also decide which of the available technologies to adopt. Finally, in the third stage, the manager of

⁴In the case where the variable cost technique is common, the free transfer of knowledge does not occur.

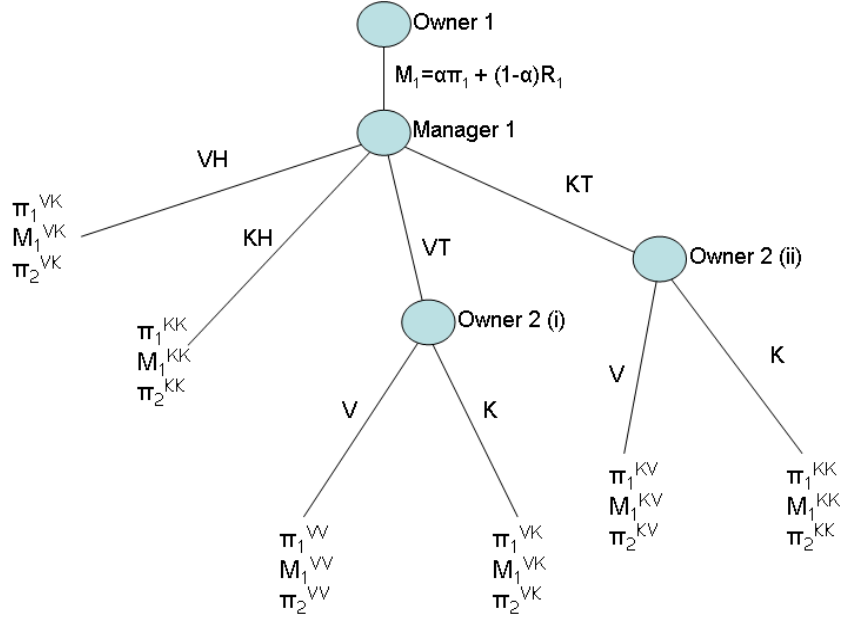


Figure 1: The Game Tree

firm 1 and the owner of firm 2 simultaneously choose quantities in a Cournot game, taking the technology choices and α as given.

At stage 3, the manger of firm 1 chooses output q_1 to maximize M_1 ; depending on the technology combination chosen at stage 2, there are potentially four different versions of (2), and these are denoted by $M_1^j, j = \{VK, KK, VV, KV\}$ where the first element in each technology pair denotes the technology choice of manager of firm 1 and the second is the choice made by firm 2.

3 Equilibrium analysis

The game is solved by backwards induction. At stage 3 production decisions are made simultaneously by the manager of firm 1 and the owner of firm 2. For the manager of firm 1 the Cournot reaction functions with technology V

and technology K are:

$$q_1^V = \frac{1 - q_2^j - \alpha c}{2}, j = VK, VV \quad (3)$$

$$q_1^K = \frac{1 - q_2^j}{2}, j = KK, KV \quad (4)$$

If the manager uses technology V , a decrease in α means that the variable cost receives less weight, causing more aggressive behavior by this firm in the product market. With technology K , α has no direct effect on the level of output chosen by the manager.

For the four potentially different combinations of technology that may be used at this stage, the equilibrium payoffs in the product market to the manager of firm 1 (M_1) and the owners of each firm (π_1 and π_2) are given in Table 1

Table 1. The equilibrium payoffs

	π_1	M_1	π_2
KK	$\frac{1}{9} - F$	$\frac{1}{9} - \alpha F$	$\frac{1}{9} - F$
KV	$\frac{(1+c)^2}{9} - F$	$\frac{(1+c)^2}{9} - \alpha F$	$\frac{(1-2c)^2}{9}$
VK	$\frac{(1+\alpha c-3c)(1-2\alpha c)}{9}$	$\frac{(1-2\alpha c)^2}{9}$	$\frac{(1+\alpha c)^2}{9} - F$
VV	$\frac{(1+\alpha c-2c)(1+c-2\alpha c)}{9}$	$\frac{(1-2\alpha c+c)^2}{9}$	$\frac{(1-2c+\alpha c)^2}{9}$

The incentives of firm 1 to disclose knowledge about a production technology to firm 2 depends on the level of F and c . To ensure positive quantities and profits in all cases, we assume that $F < \frac{1}{9}$ and $c < \frac{1}{2}$.⁵ Define the decision regarding technology as $\{x; (y, z)\}$ where $x = \{KT, KH, VT, VH\}$ is the decision of the manager of firm 1. (y, z) is the technology adoption strategy of firm 2 given that V is transferred by manager 1; y is the technology choice by 2 if manager 1 adopts V (i.e. plays VT at stage 2) and z represents the decision if manager 1 uses technology K (following 1's choice of KT). The following lemma presents the equilibrium in the subgame starting at stage 2 depending upon the relationship between F and c , where comparison of M_1^{KV} and M_1^{VV} are made.

Lemma 1 *Fix a value of α from stage 1.*

i) Let $0 < F < \frac{4c(1-c)}{9} \equiv F^I$ then the subgame starting at stage 2 has two subgame perfect Nash equilibria (SPNE):

$$\{KT; (K, K)\} \text{ and } \{KH; (K, K)\}$$

⁵The strictest conditions here are $q_1^{VK}(\alpha = 1) = q_2^{VV}(\alpha = 0) = q_2^{KV} = \frac{1-2c}{3} > 0$, and $\pi_1^{KK} = \pi_2^{KK} = \frac{1}{9} - F > 0$.

leading to the technology pair KK .

ii) Let $F^I < F < \frac{4c(1-c+\alpha c)}{9} \equiv F^{II}(\alpha)$ then the subgame starting at stage 2 has a unique SPNE:

$$\{KT; (K, V)\}$$

leading to the technology pair KV .

iii) Let $F^{II}(\alpha) < F < \frac{1}{9}$ then the subgame starting at stage 2 has a unique SPNE

$$\{VT; (V, V)\}$$

leading to the technology pair VV .

Equilibrium payoffs to all players from each of these cases in equilibrium are as given in Table 1 for the relevant technology pair.

Proof. See the Appendix

This lemma implies that when the fixed cost is small, firms will adopt technology K and the manager of firm 1 is indifferent between transferring technology V or not. When the fixed cost increases, firm 1 wants to transfer the second technology to the rival. In equilibrium, when $F^I < F < F^{II}(\alpha)$, manager 1 chooses the fixed cost technology (K) and firm 2 adopts the variable cost technology (V), and thereby firm 1 achieves higher profits and quantity than firm 2. In the last case, as F increases more, both firms rationally adopt technology V .

Notice that the three cases in Lemma 1 give rise to different combinations of technology, and that the three cases can be distinguished according to the value of F . When this fixed cost is very small, both firms adopt the fixed cost technology and no choice of α affects the results; when F is very large (above $F^{II}(\alpha = 1)$) then case (iii) prevails independent of the choice of α . When $F^I = F^{II}(\alpha = 0) < F < F^{II}(\alpha = 1)$, the owner of firm 1 has the possibility of influencing which of case (ii) or (iii) is the continuation of the subgame perfect Nash equilibrium. Hence the optimal choice of α will reflect the choice of the equilibrium that the owner of firm 1 wishes to implement; to the extent that the equilibrium profit then depends upon α , the manager can set this parameter to give the largest payoff possible from this equilibrium. Suppose that the owner of firm 1 sets α so that we are in case (iii) in Lemma 1 achieving a payoff of π_1^{VV} , which is strictly concave in α . The value of α that maximizes this expression is:

$$\alpha^* = \frac{5c - 1}{4c} \quad (5)$$

but this is only a valid choice as long as $\frac{1}{9} > F > F^{II}(\alpha^*) = \frac{(3+c)c}{9}$ and $1 > \alpha^* > 0$, conditions that in combination imply a range for c of $-2\sqrt{70} + 17 \approx 0.2668 > c > \frac{1}{5}$.

Which technology the manager of firm 1 wants to adopt in the second stage depends on α , since F^{II} is a function of α . At stage 1 the owner of firm 1 can choose $0 \leq \alpha \leq 1$. When $\alpha = 0$ the owner of firm 1 directs his manager away from profit maximization to only including revenue incentives. For $F > F^I$ this gives the technology choice of VV because $F^{II}(\alpha = 0) \equiv F^I$, and from Lemma 1 we have that $M_1^{VV} > M_1^{KV}$ when $F > F^{II}$. If $\alpha = 1$ the owner gives no other incentives to the manager than pure profit maximization, and the manager of firm 1 chooses technology K when $F < F^{II}(\alpha)$, the same technology adoption as Bacchiega and Garella (2008). In the region where $F < F^I = F^{II}(\alpha = 0)$ and $F > F^{II}(\alpha = 1)$, α has no effect on the technology adopted and the incentive to transfer knowledge to firm 2. Hence, it is only when $F^I = F^{II}(\alpha = 0) < F < F^{II}(\alpha = 1)$ that the owner of firm 1 can affect the technology choice of his manager. The choice made involves comparison of π_1^{VV} and π_1^{KV} for different values of α , c and F . The results of these comparisons are summed up in the following proposition.

Proposition 1 *I) For $F^I = F^{II}(\alpha = 0) > F > 0$, no choice of α affects the equilibrium. Profits are π_1^{KK} and π_2^{KK} .*

II) For $F^I < F < \frac{c(34-c)-1}{72} \equiv F^{IV}$ and $\frac{1}{2} > c > \frac{1}{5}$, and $F^I < F < \frac{c(1+c)}{3} \equiv F^{III}$ and $\frac{1}{7} < c < \frac{1}{5}$, the optimal choice of α is

$$\alpha \in \left(\frac{9F - 4c(1-c)}{4c^2}, 1 \right)$$

and the owner of firm 1 gets π_1^{KV} and firm 2 gets π_2^{KV} .

III a) For $\frac{1}{9} > F > F^{IV}$ and $-2\sqrt{70} + 17 \approx 0.2668 > c > \frac{1}{5}$ the optimal choice of α is

$$\alpha^* = \frac{5c - 1}{4c}$$

and the owner of firm 1 gets $\pi_1^{VV}(\alpha^)$ and firm 2 gets $\pi_2^{VV}(\alpha^*)$.*

III b) For $\frac{1}{9} > F > F^{III}$ and $\frac{1}{7} < c < \frac{1}{5}$, and $\frac{1}{9} > F > F^I$ and $0 < c < \frac{1}{7}$ the optimal choice of α is

$$\alpha = 0$$

and the owner of firm 1 gets $\pi_1^{VV}(\alpha = 0)$ and firm 2 gets $\pi_2^{VV}(\alpha = 0)$.

Proof. See the Appendix

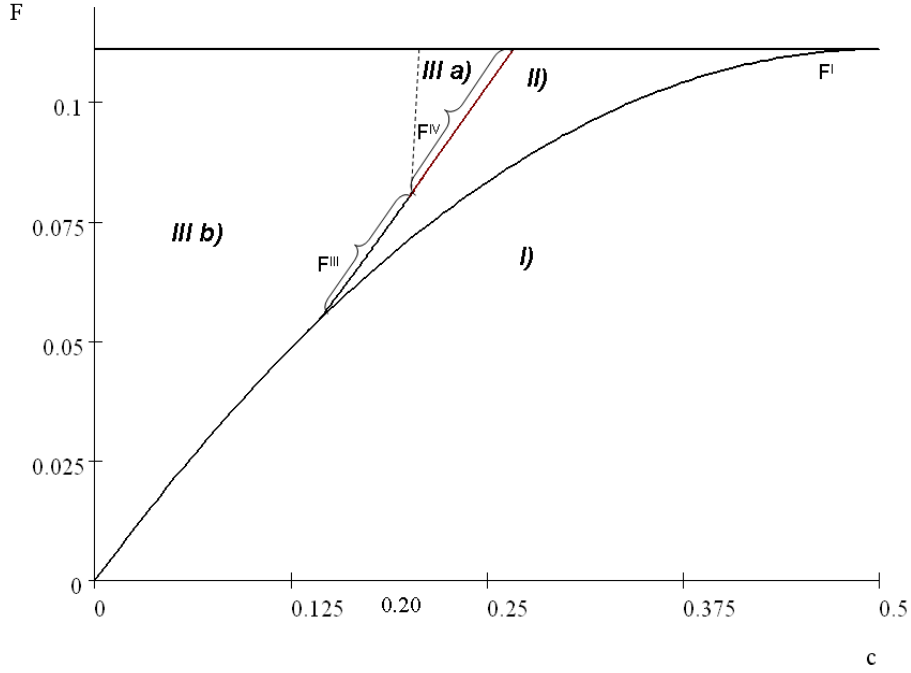


Figure 2: Optimal α

Figure 2 summarizes Proposition 1. The area I below the F^I -curve corresponds to part I of Proposition 1; here we see that the fixed cost technology is relatively inexpensive in relation to the alternative and that this leads both firms to adopt technology K even if another technology is available. There is no scope for changing this by strategic management of the type considered here.

In area II (part II of Proposition 1), the optimal choice of technology pair is KV . The owner of firm 1 finds it optimal to induce his manager to choose the fixed cost technology and transfer the knowledge about the variable cost technology to firm 2. To manage that, the owner of firm 1 has to choose the optimal α to ensure that $F < F^{II}(\alpha)$, which gives the optimal level of $\alpha \in \left(\frac{9F-4c(1-c)}{4c^2}, 1 \right)$. From Lemma 1, when the fixed cost increases, the best response of firm 2 is to adopt the transferred technology.

In the last case, in areas III a and b, the technology pairs represented to the left of the F^{III} - and F^{IV} -curves have such a large fixed cost that both firms want to adopt technology V . In this case we have that $\pi_1^{VV}(\alpha^*) > \pi_1^{KV}$ for $c > \frac{1}{5}$ (part III a of the proposition) and $\pi_1^{VV}(\alpha = 0) > \pi_1^{KV}$ for $c < \frac{1}{5}$ (part III b of the proposition). The optimal incentive scheme is to place less weight on the costs (part III a), which makes the manager of firm 1

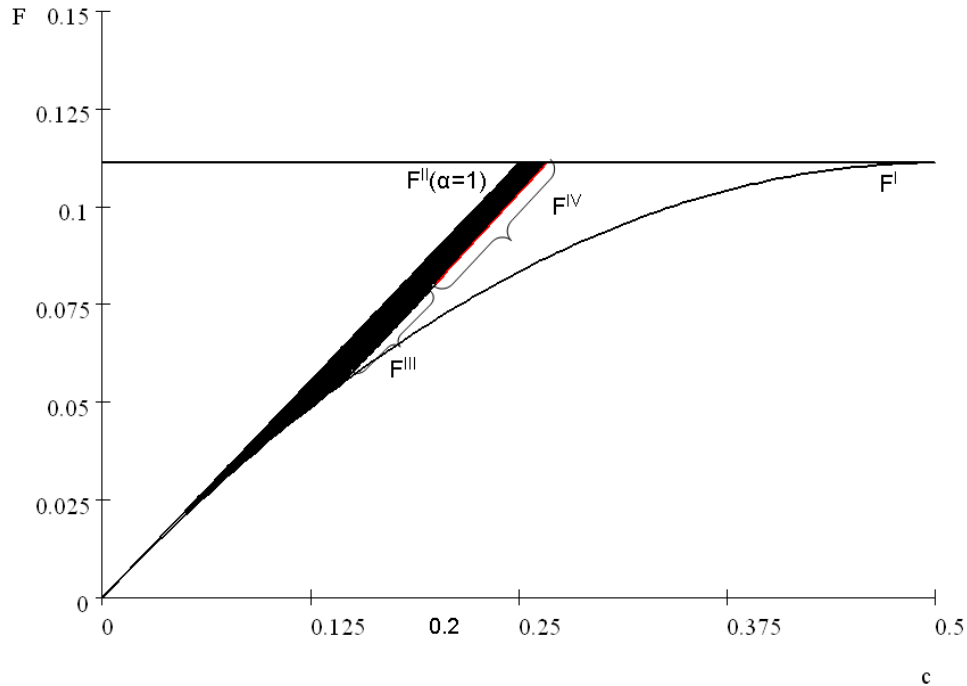


Figure 3: Comparison of the model with strategic management to the BG model

more aggressive in the output market. When the marginal cost associated with technology V becomes very small for the firms, they will both behave aggressively in the output market. Then the most profitable for the owner of firm 1 is to direct his manager away from profit maximization to only including sales incentives (part III b). In maximizing its profit, firm 2 also chooses to adopt the constant returns to scale technology.

Figure 3 compares our results to those of Bacchiega and Garella (2008) (i.e. $\alpha = 1$). In the area to the left of the $F^{II}(\alpha = 1)$ -curve there is no scope for changing the technology choice by strategic management. The dark area in Figure 3 shows where strategic management can affect the firms' behavior in equilibrium. In the model of BG, equilibria that involve the transfer of technology V to its rival are also such that firm 1 adopts K itself and acts aggressively in the product market. With strategic management of the type considered here, the owner of firm 1 can place less weight on marginal costs when technology V is adopted by his manager. Thus, the owner of firm 1 in effect no longer has to make a dichotomous choice between technology with constant or increasing returns to scale, but can use the incentive scheme to mimic a constant returns to scale technology with a lower marginal cost.

This can make the choice of V optimal for the manager of firm 1, in contrast to the BG model.

4 Welfare aspects

We consider the welfare implications of strategic management by comparing the technology choices made by the managerial firm and the entrepreneurial counterpart with the technology choices made by a social planner. We also study the case where the planner only can affect the optimal level of α from a social welfare perspective compared to the private market solution of the previous section. The social welfare function $W(Q)$ is defined as the sum of consumer surplus $CS(Q)$ and profits

$$W(Q) = CS(Q) + \pi_1 + \pi_2$$

where $CS(Q) = \frac{Q^2}{2}$. If the manager of firm 1 is given an incentive scheme that makes him act as if the marginal production cost is αc , and both firms use technology V , then social welfare can be written as

$$W^{VV}(\alpha) = -\frac{c^2}{18}\alpha^2 + \frac{c(2c-1)}{9}\alpha + \frac{5c^2}{18} - \frac{7c}{9} + \frac{4}{9} \quad (6)$$

In the absence of an incentive scheme social welfare in this case is recovered by setting $\alpha = 1$ in (6).⁶ If the technology combination is KV , then social welfare is independent of α , and is given by

$$W^{KV} = W^{VK} = \frac{c}{18}(11c-8) + \frac{4}{9} - F \quad (7)$$

With technology choices KK , the social-welfare function is again independent of α and given by

$$W^{KK} = \frac{4}{9} - 2F \quad (8)$$

4.1 Planner dictates technology

To start with, we assume that a planner can dictate the technology choice of both firms, and the firms take their own decisions in the product market. The choice of technology adoption made by the planner involves comparison of (6) with $\alpha = 1$, (7) and (8).

⁶From 6 we have $W^{VV}(\alpha = 1) = \frac{4(c-1)^2}{9}$

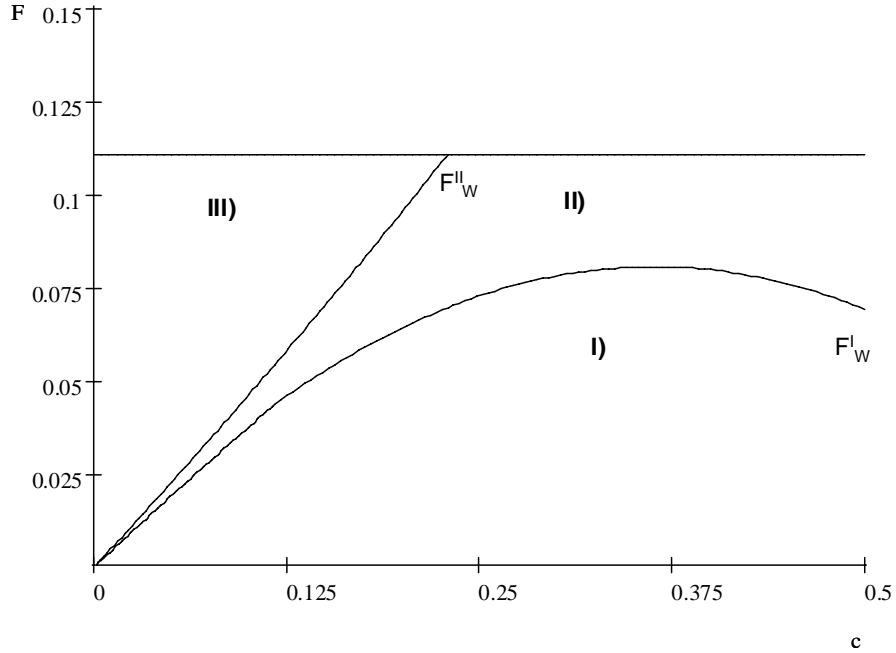


Figure 4: Technology choices dictated by the planner

Figure 4 demonstrates the technology choice in equilibrium from a welfare point of view. When the fixed cost is small compared to the variable cost, when $F < \frac{c(8-11c)}{18} \equiv F_W^I$ ⁷ (area I in figure 4), the optimal technology pair is KK . Increasing fixed costs, for $F_W^I < F < \frac{c(8+3c)}{18} \equiv F_W^{II}$ (area II in the figure), leads to $W^{KV} = W^{VK} > W^{KK}$ and the technology pair KV or VK . For $F > F_W^{II}$ (area III in the figure), where $W^{KV} = W^{VK} < W^{VV}$, the planner chooses technology pair VV .

The comparison of the equilibrium in the private market versus the socially first-best equilibrium is characterized by the following proposition. The subscript P is from the private market solution from section 3, and W is from a welfare point of view.

Proposition 2 *I) For $F_W^I < F < F_P^I$ the private solution gives technology pair KK , while the planner would prefer the adoption of the fixed cost technology (K) by one firm and the variable cost technology (V) by the other firm. Hence, $W^{VK} = W^{KV} > W^{KK}$ and, for a given combination of F and*

⁷From the inequality $W^{KK} > W^{KV} = W^{VK}$

c in this area, the loss in welfare is $-\frac{c}{18}(11c - 8c) - F$.⁸

II) For $F_P^{IV} < F < F_W^{II}$ and $-2\sqrt{70} + 17 > c > \frac{1}{5}$, $F_P^{III} < F < F_W^{II}$ and $\frac{1}{7} < c < \frac{1}{5}$, and $F_P^I < F < F_W^{II}$ and $0 < c < \frac{1}{7}$ the planner chooses the technology pair KV or VK , while the private solution is VV . For a given combination of F and c in this area, the loss in welfare is $F - \frac{4}{9}c - \frac{1}{6}c^2$.⁹

This proposition implies that the welfare optimal choice of technology pair is more often VK or KV than in the private market, where the actors prefer KK for low fixed cost and VV when the fixed cost increases compared to the variable cost. In their choice of technologies, the firms' decisions represent only their private incentives. Specifically, neither takes account of the effect that own decisions have on the rival, and neither firm thinks about how their actions affect the consumers. The planner of course takes all of this into account. Interestingly, when the firms would have chosen KK as the technology pair, the planner prefers diverging technologies even though this leads to a lower level of consumer surplus. The planner thus opts to eradicate the duplication of fixed costs in the industry at the expense of the consumers. This type of "regulation" would appear to be at odds with the widely accepted view in competition law that consumers' interests should receive most weight.

Figure 5 demonstrates the result of the comparison, where area A indicates the combinations of F and c relating to part I) of Proposition 2, and area B corresponds to part II).

4.2 The planner's choice of the incentive scheme

Let us now assume that the planner does not have the power to dictate the technology choices of both firms, but that he can set α ; one can imagine for example that firm 1 is partly owned by society. We can then consider the welfare implications of strategic management by comparing the optimal level of α from a social welfare perspective and the private market solution of section 3. From the expression (6) it is clear that W^{VV} is a strictly concave function of α and that it attains its maximum for $\alpha < 0$ for permissible values of c . Hence W^{VV} is maximized for $\alpha = 0$, giving a welfare level of

$$W^{VV}(\alpha_W = 0) = \frac{1}{18}(4 - 5c)(2 - c) \quad (9)$$

⁸From the expression $\frac{4}{9} - 2F - (\frac{c}{18}(11c - 8) + \frac{4}{9} - F)$, where $W^{KK} = \frac{4}{9} - 2F$ and $W^{VK} = W^{KV} = \frac{c}{18}(11c - 8) + \frac{4}{9} - F$.

⁹From the expression $\frac{4(c-1)^2}{9} - (\frac{c}{18}(11c - 8) + \frac{4}{9} - F)$, where $W^{VV} = \frac{4(c-1)^2}{9}$ and $W^{VK} = W^{KV} = \frac{c}{18}(11c - 8) + \frac{4}{9} - F$.

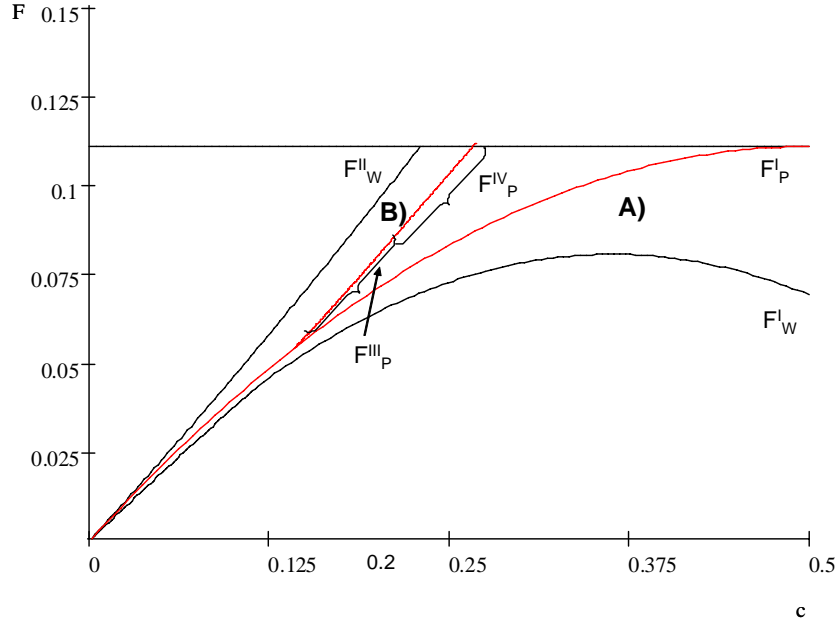


Figure 5: Comparison of equilibrium in the private market versus the socially first-best equilibrium

When $F_P^{II}(\alpha = 1) > F > F_P^I = F_P^{II}(\alpha = 0)$, a planner can choose which of the equilibria VV or KV he would prefer to be implemented. Comparison of (7) and (9) gives the result that $W^{VV}(\alpha_W = 0) > W^{KV}$ for $F > \frac{c(1+c)}{3} \equiv F_W^{III}$. Hence, for F in this region, the planner will set $\alpha = 0$ for $F > F_W^{III}$ with ensuing equilibrium characterized by technology transfer and use by both firms; when $F < F_W^{III}$, on the other hand, the equilibrium involving technology choices KV will be preferred, and α will be set to achieve this. The required α will be in the region $1 \geq \alpha > \frac{9}{4c^2} \left(\frac{4c(c-1)}{9} + F \right)$.¹⁰ When $F < F_P^I$ there is no choice of α that will affect the decisions of the firms so it can be set arbitrarily.

Comparing the planner's equilibrium with the equilibrium in the private market, we find that in the region $F_P^{IV} < F < F_W^{III}$ for $-2\sqrt{70} + 17 > c > \frac{1}{5}$ the owner of firm 1 chooses $\alpha^* = \frac{5c-1}{4c}$ resulting in VV , while the planner prefers $1 \geq \alpha > \frac{9}{4c^2} \left(\frac{4c(c-1)}{9} + F \right)$ which gives KV . For a given pair F, c in this region the loss in welfare compared to the private solution is

¹⁰The expression on the right-hand-side of the inequality is such that $F^{II}(\alpha) = F$.

$$\begin{aligned}
W^{VV}(\alpha^*) - W^{KV} &= \frac{15}{32}(c-1)^2 - \left(\frac{c}{18}(11c-8) + \frac{4}{9} - F \right) \\
&= F - \frac{71}{144}c - \frac{41}{288}c^2 + \frac{7}{288}
\end{aligned}$$

In the region above F_W^{III} and $\frac{1}{6}\sqrt{21} - \frac{1}{2} > c > \frac{1}{5}$ the planner wants to set $\alpha = 0$ (giving VV) but the private solution is α^* and the loss in welfare is

$$\begin{aligned}
W^{VV}(\alpha^*) - W^{VV}(0) &= \frac{15}{32}(c-1)^2 - \left(\frac{1}{18}(4-5c)(2-c) \right) \\
&= \frac{55}{288}c^2 - \frac{23}{144}c + \frac{7}{288}
\end{aligned}$$

This is summed up in the following proposition:

Proposition 3 *I) For $F_P^{IV} < F < F_W^{III}$ the optimal incentive scheme for a planner is $\alpha \in (\frac{9F-4c+4c^2}{9}, 1]$, while the owner of firm 1 chooses α^* .*

II) For $F > F_W^{III}$ and $c > \frac{1}{5}$ the planner chooses $\alpha = 0$, and the owner of firm 1 chooses α^ .*

III) For $F > F_W^{III}$ and $c < \frac{1}{5}$ then the social optimum is obtained by the market; $\alpha = 0$.

Figure 6 diagrammatically summarizes Proposition 3. In area I, corresponding to part I in Proposition 3, the owner of firm 1 and the planner choose different incentive schemes to maximize profits and welfare, which involves different optimal choices of technology: VV in the private equilibrium and $KV = VK$ in the welfare equilibrium. In area II (part II of Proposition 3) the owner of the managerial firm strategically places weight on both profits and revenue in the incentive scheme, while the planner prefers the manager to maximize revenue only. The optimal technology pair is VV for both cases. In area III (part III of Proposition 3), the social optimum is obtained by the market, where the incentive scheme for the manager of firm 1 only includes an incentive to maximize revenue.

5 Conclusion

In this paper we have studied the managerial incentives of a firm to freely transfer knowledge about a production technology to its rival. We have found that a separation of ownership and management will not necessarily change

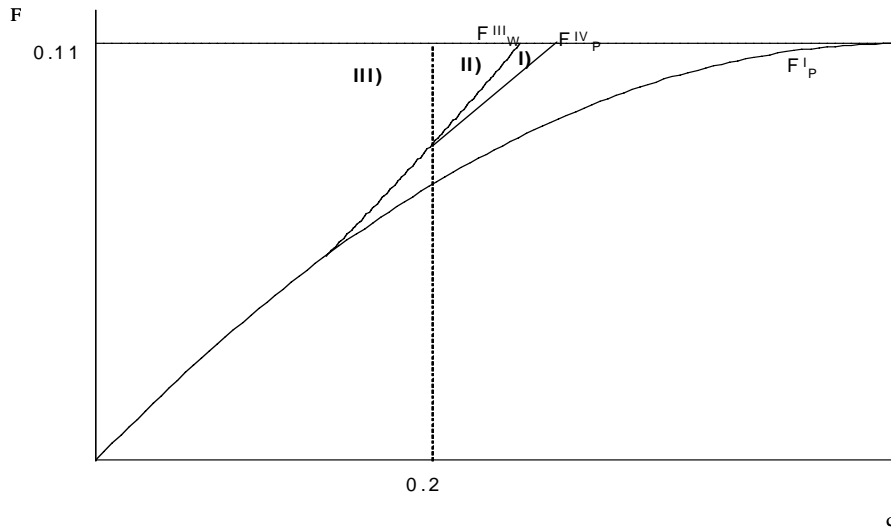


Figure 6: Comparison of the optimal incentive scheme for the owner of firm 1 versus the social planner

the incentives to transfer knowledge about a new technology to a rival. We identify conditions, however, under which it affects the technology choice of the managerial firm, and hence the intensity of competition in the product market. The owner of the managerial firm can affect the technology choice of its manager through the settings of the incentive scheme. In effect, the adoption of an incentive scheme that weights profits and income gives the owner of the managerial firm the possibility of selecting the type of equilibrium that he finds most beneficial (in terms of giving the most profit). In the optimal setting of the incentive scheme, the owner has to take account of the effect that this will have on the technology adoption by the rival firm (if new technology is transferred) and its own manager's subsequent choice of technology. Each technology pair that is chosen by the actors leads to a different outcome in the product market. In addition to influencing the technology pair, the owner can credibly distort the incentives of its manager away from pure profit maximization in order to make the opposing firm less aggressive in the product market. Transferal of knowledge can make the rival firm more efficient in equilibrium, and in some case the disclosing firm actually adopts the less efficient technique. In this paper we have demonstrated that this effect can be mitigated when the technologically more advanced firm is run by a manager with other incentives than pure profit maximization. By breaking the dichotomy of the technology choice through the incentive scheme, the managerial firm chooses also to adopt the transferred technology, compared

to the model without strategic management. If the owner fails to take into effect the full effect of its incentive scheme in this environment, then the loss of profit that this can entail may be substantial.

Furthermore, we compare the welfare equilibrium to the optimal market solution. We analyze two different cases. In the first case the social planner can dictate the firms' adoption of technology. This results in choosing different technologies for the firms more often than the market equilibrium; this occurs both for small and high values of the fixed and variable cost. In the other case, where the social planner does not have the opportunity to dictate the technology choices made by the firms, we assume that the more advanced firm is a part publicly owned firm, and the planner may maximize welfare by choosing an incentive scheme for the manager. When the variable cost is small the socially optimal incentive scheme is to direct the manager away from strict profit maximization to only include revenue; this is the exact same solution that is obtained by the market.

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APPENDIX

Proof of Lemma 1

i) If $0 < F < F^I = F^{II}$ ($\alpha = 0$) then the following inequalities hold:

$$\begin{aligned} M_1^{VV} < M_1^{KV} \text{ and } \pi_2^{VV} < \pi_2^{VK} &\implies F < F^{II}(\alpha) \\ M_1^{VK} < M_1^{KK} \text{ and } \pi_2^{KV} < \pi_2^{KK} &\implies F < F^I = F^{II}(\alpha = 0) \end{aligned}$$

Firm 2 chooses technology K at both decision nodes, hence the best the manager of firm 1 can do is to choose strategy KT or KH . (The manager of firm 1 is indifferent between KH and KT)

ii) If $F^I = F^{II}$ ($\alpha = 0$) $< F < F^{II}(\alpha)$ then the following inequalities hold:

$$\begin{aligned} M_1^{VV} < M_1^{KV} \text{ and } \pi_2^{VV} < \pi_2^{VK} &\implies F < F^{II}(\alpha) \\ M_1^{VK} > M_1^{KK} \text{ and } \pi_2^{KV} > \pi_2^{KK} &\implies F > F^I = F^{II}(\alpha = 0) \\ M_1^{KV} > M_1^{VK} &\implies F < \frac{c(2 + 4\alpha) + c^2(1 - 4\alpha^2)}{9\alpha} \equiv F^V \end{aligned}$$

At node (i) in Figure 1, firm 2 chooses technology K , and technology V is chosen at node (ii). Given these actions, manager 1 finds it optimal to choose KT if $F < F^V$ and since $F^{II} < F^V$ this inequality holds.

iii) If $F^{II}(\alpha) < F < \frac{1}{9}$ then the following inequalities hold:

$$\begin{aligned} M_1^{VV} > M_1^{KV} \text{ and } \pi_2^{VV} > \pi_2^{VK} &\implies F > F^{II}(\alpha) \\ M_1^{VK} > M_1^{KK} \text{ and } \pi_2^{KV} > \pi_2^{KK} &\implies F > F^V \end{aligned}$$

Firm 2 chooses technology V for both decision nodes, and VT is also the best response for the manager of firm 1 when $F > \frac{4c(1+c-\alpha c)}{9} \equiv F^{VI}$ and since $F^{II} > F^{VI}$ this holds.

Proof of Proposition 1

I) In the region $0 < F < F^I$ then no choice of α has any effect on the equilibrium

II) In the region $F^I < F < \frac{c(34-c)-1}{72} \equiv F^{IV}$ and $\frac{1}{2} > c > \frac{1}{5}$ we have that $\pi_1^{VV}(\alpha^*) < \pi_1^{KV}$, and in the region $F^I < F < \frac{c(1+c)}{3} \equiv F^{III}$ and $c < \frac{1}{5}$ we have that $\pi_1^{VV}(\alpha = 0) < \pi_1^{KV}$. From Lemma 1, to achieve π_1^{KV} , we need $F < F^{II}(\alpha) = \frac{4c(1-c+\alpha c)}{9}$. This expression gives the optimal choice of α in the interval

$$1 > \alpha > \frac{9F - 4c(1 - c)}{4c^2}$$

From $F^I < F < F^{III}$ we have $c > \frac{1}{7}$.

III a) We define α so $F > F^{II}(\alpha)$ and in this region Lemma 1 gives the profit of the owner of firm 1 as $\pi_1^{VV} = \frac{(1+\alpha c-2c)(1+c-2\alpha c)}{9}$. This expression is maximized for

$$\alpha^* = \frac{5c - 1}{4c}$$

which gives the owner of firm 1 $\pi_1^{VV}(\alpha^*) = \frac{1}{8}(1-c)^2$. To ensure that α^* is the optimal choice we need $\pi_1^{VV}(\alpha^*) > \pi_1^{KV}$, which requires

$$\frac{1}{9} > F > \frac{c(34-c)-1}{72} \equiv F^{IV} \quad (10)$$

From (10) and with the requirement that $\alpha^* > 0$, c will be in the region

$$-2\sqrt{70} + 17 > c > \frac{1}{5}$$

III b) In the region $F > F^{II}(\alpha)$ and for $0 < c < \frac{1}{5}$, the best response for the owner of firm 1 is to choose

$$\alpha = 0$$

since π_1^{VV} attains its maximum for $\alpha < 0$, hence π_1^{VV} is maximized for $\alpha = 0$. We have then that $\pi_1^{VV}(\alpha = 0) = \frac{(1-2c)(1+c)}{9}$ and $\alpha = 0$ is optimal for $\pi_1^{VV}(\alpha = 0) > \pi_1^{KV}$, which requires

$$\frac{1}{9} > F > \frac{c(1+c)}{3} \equiv F^{III}$$

for $\frac{1}{7} < c < \frac{1}{5}$ since $F^{III} > F^I$ when $c > \frac{1}{7}$. For $0 < c < \frac{1}{7}$ we have that $\pi_1^{VV}(\alpha = 0) > \pi_1^{KK}$ when

$$\frac{1}{9} > F > \frac{4c(1-c)}{9} \equiv F^I$$