E C O N O M I C S   B U L L E T I N

Technological spillover and the time distribution of licenses

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Abstract

The aim of this note is to study the optimal licensing of a non drastic cost reducing patented innovation, if the patent holder facing spillover is not only concerned with the optimal number of licenses, but also with their time distrbution. A simple three agents model, a patentee and two adopting firms, elucidates the conditions under which the patent holder prefers exclusive innovation exploitation, giving rise to a monopoly, non exclusive exploitation giving rise to a duopoly of simultaneous adoption or a mix of exclusive exploitation in the first period and non exclusive one in the second period, giving rise to a diffusion process. The results show that for very small cost reductions the patent holder prefers early simultaneous adoption, whereas diffusion, implying asymmetric adoption, is better if the innovation implies a more substantial cost reduction, coupled with a sufficient spillover. Exclusive license is limited to a consistent innovation with very little spillover.

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1 Introduction

Aoki and Tauman (2001) recently dealt with the optimal licensing of a cost reducing patented innovation when there is spillover: in particular the case of an outside patent-holder concerned with the optimal number of licenses sold by auction.[1] They found that if the innovation is relatively significant the patentee sells more licenses, as compared with the case of no spillover and consumers are better off.

The aim of this note is to consider what happens if the patent-holder facing spillover is not only concerned with the optimal number of licenses, but also with their time distribution, shaping the diffusion process. The spread of licenses becomes relevant if spillover is not assumed instantaneous, as in the Aoki and Tauman model, but the reduction in non licensees' costs takes a positive time lag to take place. Such assumption seems reasonable because spillover, which might be unintentional, as positive externalities take place, or intentional, consequent to a weak patent breadth, is likely to be a time-intensive process based on learning.

The patentee strategy is modelled as a first price auction where a predetermined number of licenses, endowed with different degree of exclusivity, are sold. A very simple three-stage model is employed with three players: a patent-holder and two potential licensees. In the first stage the patentee having a non drastic cost reducing innovation decides which licenses to auction in order to maximise licensing profits: the alternatives are to sell one exclusive license for two periods, giving rise to a monopoly, two non exclusive licenses for two periods, giving rise to a duopoly of early simultaneous adoption or auctioning an exclusive license for period one and two licenses for period two, implying asymmetric adoption, indicated as diffusion. In the second stage, the two firms decide independently and simultaneously how much to bid for a license; in the third stage each firm, licensed or unlicensed, determines its profit maximising level of output.

The results show that for very small cost reductions the patent-holder prefers early simultaneous adoption, whereas asymmetric adoption is better if the innovation implies a more substantial cost reduction, coupled with a sufficient spillover. Exclusive license is limited to a consistent innovation with very little spillover.

While the focus is on the role actively played by the patentee in shaping the adoption process through the choice of licenses, the results are consistent with those obtained in the adoption models allowing for preemption, which are exclusively demand based.[2]

2 The game

The foregoing discussion suggests a simple game with three agents: two identical adopting firms and a patent-holder offering a cost reducing process innovation.

The two firms produce the same good with a linear cost function $c(q) = cq$ where q is the quantity produced by a firm, and $c > 0$ is the constant marginal cost of production. The inverse demand function for this good is given by $P = a - Q$, where $a > c$ and Q is the aggregate quantity.

The third player is an inventor who has got a patent for a non drastic process innovation, reducing the cost of production from c to $c - \varepsilon$, with $a - c > \varepsilon > 0$.[3] The patentee seeks to maximise profit by licensing the invention rather than using it to compete with the existing firms, in other words I am dealing with an outsider. The patentee objective is not only to decide the number of licenses, but their distribution in time, where the periods are 1 and 2. The two firms seek to maximise their profits less licensing costs, choosing the adoption dates, either period 1 or 2. The adopting firm experiences a reduction of costs from c to $c - \varepsilon$, whereas the non adopting firm experiences a reduction of cost from c to $c - \mu$ one period later, where $\mu < \varepsilon$ represents spillover effects, which might be originated by workers moving across firms or by a weak patent breadth.

The game is noncooperative and consists of three stages.

In the first stage the patentee decides in a first price sealed bid auction the best strategy in order to maximise the licensing profits: the alternatives are to auction:

a. one exclusive license for two periods, giving rise to a monopoly;
b. two non exclusive licenses for two periods, giving rise to a duopoly of simultaneous adoption;
c. one exclusive license for period one and two licenses for period two, implying asymmetric adoption, denominated as diffusion.

In the second stage, the two firms decide independently and simultaneously how much to bid for a license. In the third stage each firm, licensed or unlicensed, determines its profit maximising level of output.

The relevant solution concept is subgame perfection in pure strategies. As it is customary in such case, we work backwards from the last stage of the game to the first.

Stage 3

In the last stage of the game the two firms determine the profit maximising level of output. Three are the possible outcomes they may face: monopoly, duopoly and time-intensive asymmetric adoption with monopoly in the first period and duopoly in the second, diffusion.

(a) Monopoly in both periods.

If a firm adopts the innovation in period 1 and the rival firm doesn't adopt the innovation, either in period 1 or in period 2, the adopting firm's profit, Π_0^1, and the non adopting firm's , Π_1^0, will be:

$$\Pi_0^1 = \frac{(s+2\varepsilon)^2}{9} + r\frac{(s+2\varepsilon-\mu)^2}{9}, \qquad \Pi_1^0 = \frac{(s-\varepsilon)^2}{9} + r\frac{(s+2\mu-\varepsilon)^2}{9}, \tag{1}$$

where r is the discount factor and $s = a - c > 0$.

The superscript indicates if the firm has adopted the innovation, the subscript if the rival has adopted. 1 meand adoption in perod 1, 2 in period 2, 0 no adoption, neither in period 1 or 2.

(b) Duopoly in both periods.

If both firms adopt the innovation in period 1, each will obtain a profit equal to:

$$\Pi_1^1 = \frac{(s+\varepsilon)^2}{9} + r\frac{(s+\varepsilon)^2}{9}. \tag{2}$$

(c) Diffusion: monopoly in period 1 and duopoly in period 2.

If a firm adopts in period 1 and the rival in period 2, profits are respectively Π_2^1 for the firm adopting first and Π_1^2 for the other:

$$\Pi_2^1 = \frac{(s+2\varepsilon)^2}{9} + r\frac{(s+\varepsilon)^2}{9}, \qquad \Pi_1^2 = \frac{(s-\varepsilon)^2}{9} + r\frac{(s+\varepsilon)^2}{9}. \tag{3}$$

Stage 2

Knowing the third stage Cournot equilibrium profits in the different cases, we can proceed to the analysis of the second stage. Here the two firms independently and simultaneously decide on how much to bid for a license. Each firm takes the other firm's bid as given in deciding its own. The difference between a licensee's and non licensee's in the two periods defines the most a firm will pay for a license. The different options are.

a. One exclusive license leading to monopoly.

We first consider the case where the patentee auctions one license with the guarantee that the buyer can exclusively exploit the innovation for the two periods. The license is sold to the highest bidder at its bid price and in the event of a tie the patentee chooses arbitrarily the licensee. The succeeding firm will get a profit equal to Π_0^1 and the other will get Π_1^0. Then the most each firm is likely to bid for a license is $\Pi_0^1 - \Pi_1^0$ and, as the bid is the same, the patentee will select at random one of the two. The patentee gets

$$Y^I = \Pi_0^1 - \Pi_1^0. \qquad (4)$$

b. Two non exclusive licenses leading to duopoly.

If the patentee decides to sell two non exclusive licenses for the two periods, a minimum bid will be set such that any firm offering a bid not inferior to the one designed by the patentee, gets a license. In such case, each firm's profits will be Π_1^1. If one of the firms makes an offer smaller than that set by the patentee, its profit will be Π_1^0, and the rival's Π_0^1. Then each firm will be willing to buy the innovation if the minimum bid is not greater than $\Pi_1^1 - \Pi_1^0$. As a result both firms will get a license and the patentee will receive

$$Y^{II} = 2\Pi_1^1 - 2\Pi_1^0. \qquad (5)$$

c. One exclusive license for period 1 and two non exclusive licenses for period 2.

In the third case the patentee auctions one license for the two periods and one license only for period 2: in other words exclusive exploitation is guaranteed for period 1, but not for period 2. The minimum bid fixed by the patentee for the two periods license amounts to $\Pi_2^1 - \Pi_1^0$, and the minimum bid for the second period license to $\Pi_1^2 - \Pi_1^0$. The result is that both firms are willing to buy a license and will be indifferent to the one they are able to buy. The patentee receives

$$Y^{III} = \Pi_2^1 + \Pi_1^2 - 2\Pi_1^0 . \qquad (6)$$

Stage 1

In the first stage of the game the patentee's objective is to choose the licensing strategy which maximises licensing profits. The possible outcomes are: (a) exclusive license, giving rise to a monopoly; (b) non exclusive licenses giving rise to a duopoly of simultaneous adoption; (c) a mix of exclusive license in the first period and non exclusive one in the second period, giving rise to a diffusion process.

3 The patentee's choice

We are now in the position to write the following propositions.

Proposition 1 *Early simultaneous adoption. If* $\varepsilon < (2/3)s$ *the patent-holder will sell the license to both firms at period 1.*

Proof

The patentee prefers simultaneous early adoption as compared to a diffusion process or to an exclusive license if:

$Y^{II} > Y^{III} \Rightarrow 2s - 3\varepsilon > 0$

and

$$Y^{II} > Y^{I} \Rightarrow 2s - 3\varepsilon > -\frac{\frac{r}{1+r}\frac{\mu}{\varepsilon}5(\varepsilon - \mu)}{1 - \frac{r}{1+r}\frac{\mu}{\varepsilon}} .$$

Some algebra involving Eqs. (1)-(6) yields

$$\varepsilon < \frac{2}{3}s \quad \Rightarrow \quad Y^{II} > Y^{III}, \tag{7}$$

$$\varepsilon < \frac{2}{3}s + \frac{5r\mu(\varepsilon - \mu)}{3[\varepsilon + r(\varepsilon - \mu)]} \quad \Rightarrow \quad Y^{II} > Y^{I}. \tag{8}$$

As $\varepsilon > \mu$, if condition $Y^{II} > Y^{III}$ is fulfilled, condition $Y^{II} > Y^{I}$ will be fulfilled as well. The discount factor r doesn't play a role in proposition 1 as it doesn't appear in condition (7), whereas condition (8) is fulfilled independently on it.

Proposition 2 *Asymmetric adoption process (diffusion). If* $s > \varepsilon > (2/3)s$ *and* $\mu > (3\varepsilon - 2s)/5$, *the patent-holder will sell the licence to one firm in period 1 and to the other in period 2.*

Proof

If $\varepsilon > (2/3)s$, the patent-holder prefers to promote an asymmetric time-intensive adoption process rather than to sell the license to both firms in period 1, that is $\varepsilon > (2/3)s$ implies $Y^{III} > Y^{II}$ (see condition (7)). We have to check that the option to create an adopting monopoly is not the preferred issue, that is $Y^{III} > Y^{I} \Rightarrow 2s - 3\varepsilon > \frac{\mu}{\varepsilon}(2s - 8\varepsilon + 5\mu)$.

Some algebra shows that:

$$\mu > \frac{3\varepsilon - 2s}{5} \quad \Rightarrow \quad Y^{III} > Y^{I}. \tag{9}$$

The discount factor doesn't play a role because first period profits are identical in Y^{I} and Y^{III}, so that only second period profits are compared.

Figure 1 shows the different cases according to the values of the parameters ε and μ.

In the blank area $\mu > \varepsilon$, which is ruled out by assumption. Simultaneous adoption (SA), leading to a duopoly, requires $\varepsilon < (2/3)s$. Asymmetric adoption leading to time-intensive diffusion (D) requires $s > \varepsilon > (2/3)s$ and $\mu > (3\varepsilon - 2s)/5$, which leaves an area of incomplete adoption –only one of the two firm adopts– giving rise to a monopoly (M), where $s > \varepsilon > (2/3)s$ but

$\mu < (3\varepsilon - 2s)/5$. If $\mu = 0$ (no spillover) diffusion is not a solution any longer and only simultaneous adoption or monopolistic exploitation are relevant.

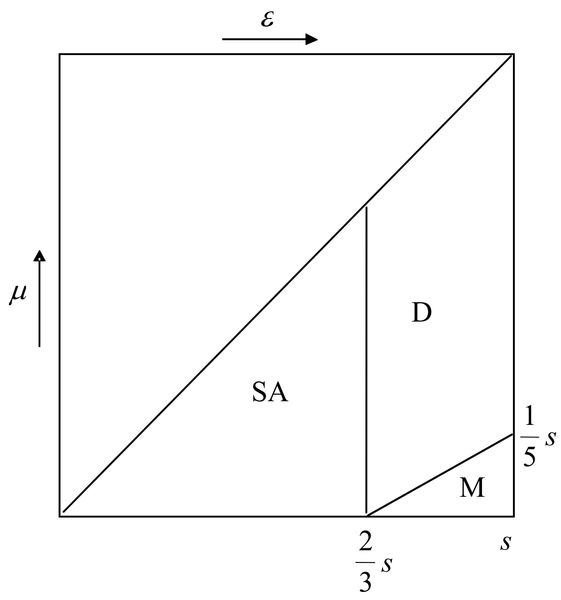

Figure 1

4 Conclusions

The results are somehow in line with those obtained in the adoption models allowing for pre-emption (Fudenberg and Tirole, 1985), as they show that for very small cost reductions the patent-holder prefers simultaneous adoption, whereas asymmetric adoption is better if the innovation implies a more consistent cost reduction, coupled with a sufficient spillover. Exclusive license is limited to a consistent innovation with very little spillover.

The fact that patent-holder strategies include not only the number but the time distribution of licenses means that innovations which would have given rise to exclusive licenses, leading to adoption mononopolies, are now sold to both adopters, though through a time intensive adoption process. The crucial role played by spillover in enabling diffusion is a well known argument in favor of thin patents.

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[1] The findings show that for an outsider patent-holder the best licensing choice is represented by auctions, followed by fixed fees, whereas royalties are the worst option. (Gallini and Winter 1985, Katz and Shapiro 1985, Kamien and Tauman 1986, Kamien, 1992 for a comprehensive survey). When the patent-holder is an incumbent, though, royalty licensing is superior to the other two options. Wang (1998), Kamien and Tauman (2002). Sen and Tauman (2002) examine general mixed licensing schemes.

[2] The theoretical models of technological diffusion can be classified according to the factor which provides the particular focus of the analysis: the role of strategic behaviour, the uncertainty inborn in the innovation itself, the possibility of increasing returns. For a comprehensive survey see Hoppe (2001).

We are here referring to the first family of models, which investigate the optimal adoption dates of n firms which are to decide when to buy a cost reducing innovation available on the market, based on strategic interaction among competing firms.

In her seminal contributions, Reinganum (1981a, 1981b) shows that n! asymmetrical Nash equilibria define the optimal adoption dates of ex ante identical firms in a precommitment model. Fudenberg and Tirole (1985) study the effects of preemption, when firms can observe and respond to their rivals' actions, obtaining the result that in a feed-back duopoly equilibrium the rents of the leader and the follower are equalised, with both asymmetric and symmetric adoption dates, according to preemption gains. See Reinganum, (1989), Beath and al., (1995), Karshenas and Stoneman (1995) and Hoppe (2001) for comprehensive surveys.

[3] The outcome in the case of a drastic innovations always implies monopolistic exploitation.