UNIVERSITY OF NOTTINGHAM

Discussion Papers in Economics

Discussion Paper
No. 10/05

Technology licensing under convex costs

Arijit Mukherjee

April 2010

2010 DP 10/05

Technology licensing under convex costs

Arijit Mukherjee

University of Nottingham and The Leverhulme Centre for Research in Globalisation and Economic Policy, UK

April 2010

Abstract: The technology licensing literature has completely dominated by the assumption of constant returns to scale technology, while the implications of convex costs have been discussed extensively in the Industrial Organization literature or in the Microeconomics literature, in general. We show that an "outside innovator" and the society may prefer royalty licensing compared to auction (or fixed-fee licensing) under convex costs. There can also be conflicting interests between the innovator and the society about the preferred licensing contract. However, the consumers always prefer auction. It follows from our analysis that a combination of royalty and fixed-fee can dominate both auction (of fixed-fee licensing) and royalty only licensing.

Key Words: Auction; Convex cost; Fixed-fee; Licensing; Royalty

JEL Classification: D43; L13

Correspondence to: Arijit Mukherjee, School of Economics, University of Nottingham, University Park, Nottingham, NG7 2RD, UK

E-mail: arijit.mukherjee@nottingham.ac.uk

Fax: + 44 115 951 4159

Technology licensing under convex costs

1. Introduction

Technology licensing is an important element of conduct in many industries and has attracted fair amount of attention in recent years. The seminal works by Kamien and Tauman (1984 and 1986) show that, if an innovator, who is not a producer,[1] licenses the technology to final goods producers and the product market is characterized by Cournot competition, licensing with output royalty generates lower profit to the innovator compared to fixed-fee licensing and auction, regardless of the industry size and/or magnitude of the innovation.[2] In view of this theoretical result, the wide prevalence of output royalty in the licensing contracts (see, e.g., Taylor and Silberstone, 1973 and Rostoker, 1984) has remained a puzzle, and has generated significant amount of interest in explaining the superiority of royalty licensing over other types of licensing contracts. The factors attributed to the presence of output royalty in a licensing contract offered by an "outside innovator"[3] are asymmetric information (Gallini and Wright, 1990, Beggs, 1992, Poddar and Sinha, 2002 and Sen, 2005b), product differentiation (Muto, 1993 and Poddar and Sinha, 2004), moral hazard (Macho-Stadler et al., 1996 and Cho, 2001), risk aversion (Bousquet et al., 1998), incumbent innovator (Shapiro, 1985, Kamien and Tauman, 2002 and Sen and Tauman, 2007), leadership structure (Kabiraj, 2004), strategic delegation (Saracho,

[1] Licensing by the Universities or independent research labs to the producers may be the examples of this scenario.
[2] See Kamien (1992) for a nice survey of this literature.
[3] Outside innovator refers to the situation were the innovator (who is the licenser) and the licensees do not compete in the product market.

2002), integer constraint on the number of licenses (Sen, 2005) and market power of the input supplier (Mukherjee, 2009).

There is a related literature which shows the superiority of royalty licensing and licensing with a combination of fixed-fee and royalty when the licenser and the licensees compete in the product market (see, e.g., Rockett, 1990, Wang, 1998 and 2002, Wang and Yang , 1999, Filippini, 2001, Mukherjee and Balasubramanian, 2001, Faulí-Oller and Sandonis, 2002, Fosfuri, 2004, Kabiraj, 2005, Poddar and Sinha, 2005 and Mukherjee, 2007). In this literature, the competition softening effect of output royalty may make the royalty licensing preferable than fixed-fee licensing if the licenser and the licensees compete in the product market.

While the literature on technology licensing has focused on several important aspects of the industry, *this literature is completely dominated by the use of constant returns to scale technologies*. Although this can be the correct reflection of many real world situations, there can be several other possible technological specifications which lead to different cost functions such as convex costs. While the implications of convex costs, which occur in the presence of diseconomies of scale, have been discussed extensively in the Industrial Organization literature or Microeconomics literature, in general, to the best of our knowledge, there is no work on technology licensing showing the effects of convex costs on the licensing contracts and welfare. This paper is a step to fill this gap.

We develop a simple model of technology licensing by an outside innovator to the Cournot oligopolists in the presence of convex costs. Considering zero opportunity costs of the licensees, which correspond to the case of drastic innovation in the sense of Arrow (1962), we show that royalty licensing may generate higher payoff to the innovator compared to auction and fixed-fee licensing, if the number of potential licensees are sufficiently large, which creates a large difference between the number of licenses under royalty licensing and auction (or fixed-fee licensing). It follows from our analysis that a combination of fixed-fee and output royalty can be preferable to the innovator compared to a royalty only licensing or auction.

We also show that there can be situations where both the innovator and the society prefer royalty licensing compared to auction (or fixed-fee licensing). There can also be the situations where the innovator prefers royalty licensing but the society prefers auction, thus creating conflicting interests between the innovator and the society about the preferred licensing contract. However, the consumers always prefer auction compared to royalty licensing.

Though royalty licensing (compared to fixed-fee licensing and auction) creates distortion in the product market by imposing positive output royalty, it helps to reduce the effects of the diseconomies of scale generating convex costs. If the number of licenses under royalty licensing is sufficiently large compared to auction (or fixed-fee licensing), royalty licensing reduces the effects of the diseconomies of scale significantly compared to auction, by dividing the total outputs over a large number of licensees under royalty licensing compared to auction. This benefit from royalty licensing makes it preferable to both the innovator and the society if the number of potential licensees are large. However, since the total outputs are important for consumer surplus, we get that the output distorting effect of royalty makes auction always preferable to the consumers.

If the number of potential licensees is not very high, royalty cannot reduce the effect of the diseconomies of scale significantly, thus making auction preferable compared to royalty licensing to both the innovator and the society. If the number of potential licensees are moderate, the benefit of royalty licensing makes the innovator better off under royalty licensing compared to auction, while the royalty's negative output distortion effect on the consumers makes auction preferable to the society, which considers both the total industry profit and consumer surplus.

The remainder of the paper is organized as follows. Section 2 describes the model and shows the results. Section 3 concludes.

2. The model and the results

Assume that there is an innovator, called I, who has invented a new product. However, I cannot produce the good. There are $n \geq 1$ symmetric potential producers of the product, and I can license its technology to the potential producers. We assume that licensing is costless. To avoid analytical complexity, we ignore integer constraint and consider the number of producers (i.e., n) as a continuous variable. To show the implications of the convex costs of production in the simplest way, we assume that each producer's opportunity cost of having a license is 0, which corresponds to the case of drastic innovation in the sense of Arrow (1962). Alternatively, we may assume that the producers are not producing any product which is in competition with the innovated product. There can be another interpretation of our framework. Assume that a developed-country producer has invented a new product and can enter a developing country only through technology licensing (due to higher costs of exporting and foreign direct investment).

Assume that the outputs of the producers are perfect substitutes, and the inverse market demand function for the product is

$$P = a - q, \tag{1}$$

for $a > q$ and $P = 0$ for $a \le q$, where P is price and q is the total output.

We assume that if the *i*th producer gets the technology and wants to produce the product, its total cost of production is $C_i = \frac{cq_i^2}{2}$, where $i = 1, 2, \ldots, n$. Hence, the marginal cost of the ith firm is cq_i, which is increasing in its output. The coefficient c determines the steepness of the cost function. Note that $c = 0$ makes our analysis similar to the previous works with constant returns to scale.

We will consider the following licensing contracts designed by I :

(i) Auctioning k licenses, $1 \le k \le n$, by I through a sealed bid English auction. The highest bidders get license. The ties are resolved by I .

(ii) Royalty licensing, where a fixed royalty payment r per unit of output is charged by I , and any producer that wishes to can purchase the license at this royalty rate.

There can be another type of licensing contract, viz., fixed-fee licensing, where the innovator charges a flat pre-determined license fee F , and any producer that wishes to can purchase the license at this fixed-fee. However, it is immediate from Kamien et al. (1992) that the essential difference between auction and fixed-fee licensing stems from the difference in producers' opportunity costs of having a license. Since we are considering a situation with zero opportunity costs of the producers, it is then immediate that auction and fixed-fee licensing give the same solution in this situation. Therefore, we focus on auction and do not consider the case of fixed-fee licensing separately in the following analysis.

The implications of licensing with both fixed-fee and per-unit output royalty where the fixed-fee can be determined either by the innovator (i.e., fixed-fee plus royalty licensing) or it can be the winning bids of the licensees if the innovator auctions off licenses (i.e., auction plus royalty licensing) will follow easily from our analysis.

We consider the following games for our analysis. Under royalty licensing, at stage 1, I announces the uniform royalty rate r. At stage 2, the producers simultaneously and independently decide whether or not to purchase a license. At stage 3, the producers choose their outputs simultaneously. If only one producer purchases a license at stage 2, he produces like a monopolist at stage 4.

Under auction, at stage 1, I announces to auction k licenses, where $1 \leq k \leq n$. At stage 2, the producers simultaneously and independently decide whether or not to purchase a license, and how much to bid. At stage 3, the producers choose their outputs simultaneously. If I auctions only one license, the licensee produces like a monopolist at stage 4. We solve these games by backward induction.

First determine the product market equilibrium. If the innovator I licenses the technology to k firms, where $1 \leq k \leq n$, and each of the k firms pays a per-unit output royalty r, where $r < a$, the ith licensee, $i = 1, 2, ..., k$, chooses his output to maximize the following expression:

$$\underset{q_i}{Max}(a - q - r)q_i - \frac{cq_i^2}{2} . \tag{2}$$

The equilibrium output of the ith licensee can be found as $q_i = \dfrac{a - r}{k + 1 + c}$, $i = 1, 2, ..., k$.

Note that r is 0 under auction, while r is positive under royalty licensing.

2.1. Royalty licensing

Under royalty licensing, each licensee always prefers to purchase a license for $r < a$, since the licensees always have the option to produce nothing after purchasing a license, thus earning 0, which is the opportunity cost of having a license.

With n licensees, the outputs of the licensees are $q_1 = q_2 = ... = q_n = \frac{a-r}{n+1+c}$. Hence, the innovator I maximizes the following expression to determine the equilibrium royalty rate:

$$\underset{r}{Max} \frac{nr(a-r)}{n+1+c}. \quad (3)$$

The equilibrium royalty rate is $r^{*,d} = \frac{a}{2}$, which is less than a, and the equilibrium profit of I is

$$\pi_r^I = \frac{na^2}{4(n+1+c)}. \quad (4)$$

2.2. Auction

Now consider the game under auction. If I auctions k licenses, where $1 \le k \le n$,[4] the outputs of the licensees are $q_1 = q_2 = ... = q_n = \frac{a}{n+1+c}$.

The profit of each licensee is $\pi_1 = \pi_2 = ... = \pi_k = \frac{a^2(2+c)}{2(k+1+c)^2}$. Therefore, in the Nash equilibrium of the bidding game, each potential licensee bids $\frac{a^2(2+c)}{2(k+1+c)^2}$.

If $k = n$, I can guarantee this equilibrium bid by specifying a minimum bid. However, for $k < n$, the producers bid these amounts even if I does not specify the minimum bid.

If I auctions k licenses, his payoff is $\pi_a^I = \frac{a^2 k(2+c)}{2(k+1+c)^2}$, and the number of licenses to auction is determined by maximizing the following expression:

$$\underset{k}{Max} \frac{a^2 k(2+c)}{2(k+1+c)^2}. \qquad (5)$$

The equilibrium number of licenses is given by

$$k^* = 1 + c. \qquad (6)$$

Therefore, in our setup, the equilibrium number of auction is k^* if $n \geq k^*$, while it is n if $n < k^*$. Hence, $\pi_a^I = \frac{a^2(2+c)}{8(1+c)}$ for $n \geq k^*$ and $\pi_a^I = \frac{a^2 n(2+c)}{2(n+1+c)^2}$ for $n < k^*$.

For simplicity, we assume in the following analysis that the parameter values are such that $n > k^*$. For example, if $c = 1$, we can satisfy $n > k^*$ for $n > 2$.

2.3. Comparing auction with royalty licensing

Proposition 1: *Consider $n > k^*$. The innovator earns higher profit under royalty licensing than under auction (or fixed-fee licensing) if $c(n-3) - c^2 > 2$.*

[4] As pointed out in Kamien et al. (1992), if the innovator auctions n licenses, each licensee is assured a license, and bids as little as possible. Hence, to induce the licensees to bid their maximum willingness to pay, the innovator needs to specify a minimum bid for $n = k$.

Proof: If $n > k^*$, the profits of I are $\pi_r^I = \frac{na^2}{4(n+1+c)}$ and $\pi_a^I = \frac{a^2(2+c)}{8(1+c)}$ under royalty licensing and under auction respectively. Straightforward calculation shows that the former is higher than the latter if $c(n-3) - c^2 > 2$. ■

It is immediate from Proposition 1 that if *c = 0*, like the previous works (see, e.g., Kamien and Tauman, 1984, 1986 and 2002), the innovator gets higher profit under auction (or fixed-fee licensing) than under royalty licensing. However, that may not be the case for *c > 0*. For example, if *c = 1*, the innovator earns higher profit under royalty licensing than under auction (or fixed-fee licensing) if *n > 6*. It is also clear from Proposition 1 that if *n* increases, it increases the profitability of royalty licensing compared to auction (or fixed-fee licensing).

The reason for the above result is as follows. Due to the diseconomies of scale, which create convex costs, diversification of outputs in multiple firms helps to increase the industry profit by reducing the total cost of production. This effect is absent under constant returns to scale technology. Hence, in our analysis, royalty licensing (compared to auction or fixed-fee licensing) creates two opposing effects on the profits of the innovator. On the one hand, like the previous works with constant returns to scale technology, royalty licensing tends to reduce the industry profit compared to auction (or fixed-fee licensing) by distorting the output choices of the licensees. On the other hand, if the number of licenses is higher under royalty licensing than under auction, the effects of diseconomies of scale is lower under the former licensing contract than the latter, which tends to increase the industry profit under royalty licensing compared to auction. If the number of potential licensees is large enough so that the innovator gives more licenses under royalty licensing than under auction, it makes the second effect stronger than the first effect, and the profit of the innovator is higher under royalty licensing than under auction (or fixed-fee licensing).

We have shown that royalty licensing can dominate auction (or fixed-fee licensing). However, it is immediate from the above analysis that a combination of royalty and fixed-fee will be optimal than the royalty licensing, since the licensees' net profits are positive under royalty licensing, which the innovator can extract through fixed-fee. It is also intuitive that a combination of royalty and fixed-fee can dominate auction (or fixed-fee licensing), since royalty helps to reduce the effects of diseconomies of scale by increasing the number of licensees, while fixed-fee helps to avoid the output distortion created by the royalty and also helps the innovator to extract more profits from the licensees.

2.4. Welfare comparison

Now we see the effects of royalty licensing and auction on consumer surplus and social welfare, which is the sum of "total profits of the innovator and the licensees, and consumer surplus". Again, we assume that $n > k^* = 1 + c$ so that the number of licenses under auction is less than the number of potential licensees, *n*.

Consumer surplus and social welfare under royalty licensing are respectively

$$CS_r = \frac{(an)^2}{8(n+1+c)^2} \tag{7}$$

$$W_r = \frac{na^2(4+3n+3c)}{8(n+1+c)^2}. \tag{8}$$

Consumer surplus and social welfare under auction are respectively

$$CS_a = \frac{a^2}{8} \tag{9}$$

$$W_a = \frac{a^2(3+2c)}{8(1+c)} . \tag{10}$$

Proposition 2: *The consumer surplus is higher under auction than under royalty licensing.*

Proof: It follows from the straightforward comparison of (7) and (9). ■

The above result is due to the standard output distortion of the licensees under royalty licensing compared to auction. Since consumer surplus depends on the total outputs of the licensees and not on the total cost of the industry, the diseconomies of scale do not play an important role for the comparison of consumer surplus, though diseconomies of scale affect the output decisions of the licensees.

Thus, Propositions 1 and 2 show that there may be conflicting interests between the innovator and the consumers about the licensing contract. Further, it is easy to understand that the net profits of the licensees (which exclude the licensing fees from the licensees' profits) are higher under royalty licensing than under auction, since the innovator cannot extract the entire profits of the licensees under royalty licensing while it can extract the entire profits of the licensees under auction. Hence, it seems that whether welfare is higher under royalty licensing or under auction is ambiguous. We will now show that this can indeed be the case.

We get that welfare is higher under royalty licensing than under auction (or fixed-fee licensing) if

$$(1+c)[n(3n-2-c)-(1+c)(3+2c)]-n^2(3+2c)>0 . \tag{11}$$

It follows immediately from (11) that condition (11) does not hold for $c = 0$, i.e., social welfare is higher under auction than under royalty licensing in the absence of convex cost. However, there can be situations where (11) holds. The following proposition will show one such possibility.

Proposition 3: *Consider $c = 1$ and the number of licensees as integers.*

(a) If $n < 6$, both the innovator and the society prefer auction (or fixed-fee licensing) compared to royalty licensing.

(b) If $n > 9$, both the innovator and the society prefer royalty licensing compared to auction.

(c) If $6 < n < 9$, the innovator prefers royalty licensing but the society prefers auction.

Proof: If $c = 1$, we get from the condition shown in Proposition 1 that the innovator prefers royalty licensing than auction (or fixed-fee licensing) if $n > 6$. On the other hand, if $c = 1$, we get that condition (11) holds, i.e., the society prefers royalty licensing compared to auction, if $n > 9$. The rest of the proof follows trivially. ■

Propositions 3(ii) and 2 show that there can be situations where both the innovator and the society prefer royalty licensing compared to auction, while the consumers prefer auction. Proposition 3(iii) shows that there can also be the conflicting interest between the innovator and the society about the preferred licensing contract.

Like Proposition 1, diseconomies of scale play an important role also for Proposition 3, since welfare consists of both the profits and consumer surplus. If there is large number of licenses under royalty licensing compared to auction, it helps to create higher welfare under the former than the latter by reducing the effect of diseconomies of scale, though royalty licensing creates output distortion.

4. Conclusion

The technology licensing literature is completely dominated by constant returns to scale technology, while the implications of convex costs have been discussed extensively in the Industrial Organization literature or Microeconomics literature, in general. Considering "outside innovator", we show that convex costs can change the preference for the licensing contracts significantly, both for the innovator and the society. If the number of potential licensees is sufficiently large (small), both (none of the) the innovator and the society prefer royalty licensing compared to auction (or fixed-fee licensing). There can be the situations where the innovator prefers royalty licensing but the society prefers auction. The consumers always prefer auction.

It may worth pointing out that we have considered that all the licensees operate a single plant. However, in the presence of convex costs, the licensees may prefer to operate multiple plants instead of single plant. Hence, it is implicit in our analysis that the operation of multiple plants is prohibitively costly to the licensees. However, if the operation of multiple plants is not very costly, the licensees may prefer to allocate their outputs among different plants in order to reduce the effect of the diseconomies of scale. Hence, along with the royalty licensing, the strategic plant choice of the licensees also tends to reduce the effect of the diseconomies of scale. It is intuitive that, since the strategic incentive for operating multiple plants remains under all types of licensing contracts, our results will hold as long as the effect of royalty licensing (compared to strategic plant choice) is more effective in reducing the effect of the diseconomies of scale.

References

Arrow, K., 1962, 'Economic welfare and the allocation of resources for invention', in R. Nelson (Ed.), *The Rate and direction of inventive activity*, Princeton University Press, Princeton.

Beggs, A. W., 1992, 'The licensing of patents under asymmetric information', *International Journal of Industrial Organization*, 10: 171-91.

Bousquet, A., H. Cremer, M. Ivaldi and M. Wolkowicz, 1998, 'Risk sharing in licensing', *International Journal of Industrial Organization*, 16: 535-54.

Choi, J. P., 2001, 'Technology transfer with moral hazard', *International Journal of Industrial Organization*, 19: 249-66.

Faulí-Oller, R. and J. Sandonis, 2002, 'Welfare reducing licensing', *Games and Economic Behavior*, 41: 192-205.

Filippini, L., 2001, 'Process innovation and licensing', *Mimeo*, Università Cattolica.

Fosfuri, A., 2004, 'Optimal licensing strategy: Royalty or fixed fee?', *International Journal of Business and Economics*, 3: 13-19.

Gallini, N. T. and B. D. Wright, 1990, 'Technology transfer under asymmetric information', *Rand Journal of Economics*, 21: 147-60.

Kabiraj, T., 2004, 'Patent licensing in a leadership structure', *The Manchester School*, 72: 188-205.

Kabiraj, T., 2005, 'Technology transfer in a Stackelberg structure: Licensing contracts and welfare', *The Manchester School*, 73: 1-28.

Kamien, M. I., 1992, 'Patent licensing', in R. J. Aumann and S. Hart (Eds.), *Handbook of game theory*, Elsevier, Amsterdam: 331-55.

Kamien, M. I. and Y. Tauman, 1984, 'The private value of a patent: A game theoretic analysis', *Journal of Economics (Zeitschrift für Nationalökonomie)*, 4 (Supplement): 93 -118.

Kamien, M. I. and Y. Tauman, 1986, 'Fees versus royalties and the private value of a patent', *The Quarterly Journal of Economics*, 101: 471-79.

Kamien, M. I. and Y. Tauman, 2002, 'Patent licensing: the inside story', *The Manchester School*, 70: 7-15.

Kamien, M. I., S. S. Oren and Y. Tauman, 1992, 'Optimal licensing of cost-reducing innovation', *Journal of Mathematical Economics*, 21: 483-508.

Kamien, M. I., Y. Tauman and I. Zang, 1988, 'Optimal license fees for a new product', *Mathematical Social Sciences*, 16: 77-106.

Macho-Stadler, I., X. Martinez-Giralt and J. D. Pérez-Castrillo, 1996, 'The role of information in licensing contract design', *Research Policy*, 25: 25-41.

Mukherjee, A. and N. Balasubramanian, 2001, 'Technology transfer in horizontally differentiated product market', *Research in Economics*, 55: 257-74.

Mukherjee, A., 2007, 'Optimal licensing contract in an open economy', *Economics Bulletin*, 12 (3): 1-6.

Mukherjee, A., 2009, 'Licensing a new product: fee vs. royalty licensing with unionized labor market', *Labour Economics*, Forthcoming.

Muto, S., 1993, 'On licensing policies in Bertrand competition', *Games and Economic Behavior*, 5: 257-67.

Poddar, S. and U. B. Sinha, 2002, 'The role of fixed fee and royalty in patent licensing', *Working Paper, No. 0211*, Department of Economics, National University of Singapore.

Poddar, S. and U. B. Sinha, 2004, ‘On patent licensing and spatial competition’, *Economic Record*, 80: 208-18.

Poddar, S. and U. B. Sinha, 2005, ‘Patent licensing from high-cost to low-cost firm’, *Working Paper, 05/03*, Department of Economics, National University of Singapore.

Rockett, K., 1990, ‘The quality of licensed technology, *International Journal of Industrial Organization*, 8: 559-74.

Rostoker, M., 1984, ‘A survey of corporate licensing’, *IDEA: The Journal of Law and Technology*, 24: 59-92.

Saracho, A. I., 2002, ‘Patent licensing under strategic delegation’, *Journal of Economics and Management Strategy*, 11: 225-51.

Sen, D., 2002, ‘Monopoly profit in a Cournot oligopoly’, *Economics Bulletin*, 4: 1-6.

Sen, D., 2005a, ‘Fee versus royalty reconsidered’, *Games and Economic Behavior*, 53: 141-47.

Sen, D., 2005b, ‘On the coexistence of different licensing schemes’, *International Review of Economics and Finance*, 14: 393-413.

Sen, D. and Y. Tauman, 2007, ‘General licensing scheme for a cost-reducing innovation’, *Games and Economic Behavior*, 59: 163-86.

Shapiro, C., 1985, ‘Patent licensing and R&D rivalry’, *American Economic Review, Papers and Proceedings*, 75: 25-30.

Taylor, C. and Z. Silberstone, 1973, *The economic impact of the patent system*, Cambridge University Press, Cambridge.

Wang, X. H., 1998, ‘Fee versus royalty licensing in a Cournot duopoly model’, *Economics Letters*, 60: 55-62.

Wang, X. H., 2002, 'Fee versus royalty licensing in a differentiated Cournot duopoly', *Journal of Economics and Business*, 54: 253-66.

Wang, X. H. and B. Yang, 1999, 'On licensing under Bertrand competition', *Australian Economic Papers*, 38: 106-19.