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Entry, licensing and welfare*

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Abstract: We show the welfare effects of entry in presence of technology licensing under Cournot competition. If the entrant is technologically inferior to that of the incumbent then, though licensing reduces (or completely eliminates) excessive entry for relatively low entry costs, it creates excessive entry for high entry costs at which entry would not occur without licensing. While excessive entry under licensing occurs for very low marginal cost of the entrant, there is insufficient entry under licensing for very high marginal cost of the entrant. The effect of bargaining power of the firms is ambiguous on our results. In contrast, if the entrant is technologically superior to that of the incumbent, licensing creates excessive entry for relatively low entry costs, while it eliminates excessive or insufficient entry for relatively high entry costs that occurs under no licensing.

Key Words: Entry; Licensing; Welfare

JEL Classification: D43; L13; O34

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1. Introduction

It is well known that free entry may not always be welfare improving in an imperfectly competitive market (Williamson, 1968, Spence, 1976, Dixit, 1977, von Weizsäcker, 1980, Perry, 1984, Mankiw and Whinston, 1986, Suzumura and Kiyono, 1987, Okuno-Fujiwara and Suzumura, 1993 and Cabral, 2004). However, one common feature of these papers is to ignore the effects of non-production activities of the firms, such as technology licensing, which is an important strategic decision in many industries (see, e.g., Calvert, 1964, Rostoker, 1984 and Taylor and Silberston, 1973) and has generated fair amount of empirical and theoretical research.[1]

[1] There is a vast empirical and theoretical literature on technology licensing. Since the purpose of this paper is not to explain the reasons for technology licensing but to show the impact of licensing on the relationship between product market competition, profits and welfare, we are not going to review the literature on licensing. However, one may refer to Rostoker (1984) and Kamien (1992) for surveys on technology licensing.

In this paper, we show how technology licensing affects the welfare effects of entry under Cournot competition. We consider two situations: first, where the entrant is technologically inferior to that of the incumbent, and second, where the entrant is technologically superior to that of the incumbent. We show that technology licensing has significant impacts on the incentive for entry and therefore, may have important implications for the competition policies designed to encourage entry.

In what follows, section 2 considers the situation where the entrant is technologically inferior to that of the incumbent. This may happen in an economy where the incumbent firm is a technology leader and holds patents for its technologies[2], but the expiration of patents for its old technologies create the threat of entry and exposes the incumbent to competition. We show that licensing reduces (or completely eliminates) the incentive for excessive entry for relatively low entry costs, whereas it creates the incentive for excessive entry for high entry costs at which entry would not occur without licensing. Licensing creates excessive entry for relatively high entry costs if the own marginal cost of the entrant is very low. But, if the own marginal cost of the entrant is very high, there is insufficient entry under licensing. We find that the effect of bargaining power of the firms is ambiguous on our results. These results suggest that ignoring technology licensing in an economy with technologically inferior entrant, the welfare effects of entry might be overestimated for low entry costs whereas it would be underestimated for high entry costs.

Section 3 considers the other situation where the entrant is technologically superior to that of the incumbent. This situation is consistent with the technological leapfrogging considered in Brezis et al. (1993), Motta et al. (1997), Chen (1999) and many others. Recently, Lee and Lim (2001) provide evidences for technological

leapfrogging in the Korean industries. We show that if the entrant is technologically superior to that of the incumbent, entry can be either excessive or insufficient for relatively high entry costs when there is no licensing. But, there can only be excessive entry under licensing and it occurs for relatively low entry costs. So, licensing in this situation creates excessive entry for relatively low entry costs, while it eliminates excessive or insufficient entry for relatively high entry costs.

Hence, the contributions of this paper are two fold. First, it shows that non-production activity such as technology licensing changes the incentive for entry, and the technological differences between the incumbent and the entrant and the bargaining power of the firms are important in this respect. Whether licensing creates excessive entry for low or high entry costs, and whether it also creates the insufficient incentive for entry depends on the technological differences between the incumbent and the entrant. Second, it shows that technology licensing may reduce social welfare by creating excessive entry, which extends the recent literature on 'welfare reducing licensing'. However, unlike the existing literature, where licensing may reduce welfare either by facilitating collusive behavior in the industry (Eswaran, 1994, Lin, 1996, Erutku and Richelle, 2000, Faulí-Oller and Sandonis, 2002) or by affecting the incentive for cooperative R&D (Mukherjee, 2005), this paper shows that *licensing may reduce welfare even if it increases competition in the product market*. So, our results are important for the policies designed to attract new firms.

Section 4 concludes the paper. The proofs are relegated to the appendices.

[2] We define technology by the marginal cost of production. Lower marginal cost of production implies better technology.

2. Entry of a technologically inferior firm

2.1 Entry without licensing

Let us consider a market with a monopolist incumbent, firm 1, and a potential entrant, firm 2. These firms can produce a homogeneous product and the inverse market demand function for the product is

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

where the notations have usual meanings.

Assume that firm 1 produces its product with the constant marginal cost of production c_1. To economize on the notations, we make a simplifying assumption that $c_1 = 0$. It is needless to say that our qualitative results hold for $c_1 > 0$. We further assume that firm 2 produces its product with the constant marginal cost of production c, where $0 < c$. As mentioned in the introduction, we assume that the expiry of the patent of an old technology of firm 1 creates the threat of entry. We also assume that $c < \frac{a}{2}$, which ensures positive output of both firms under entry without licensing. For $c > \frac{a}{2}$, firm 1 is monopoly in the product market even if entry occurs and therefore, entry has no real impact on our analysis. We further assume that the entrant incurs the entry cost, $E > 0$, for acquiring the technological knowledge, getting license to enter the market, setting up an office, paying the lawyer fees, etc. For simplicity, we assume that there is no other cost of production.[3]

Now, consider the following game. At stage 1, the entrant decides on entry. If it does not enter, the incumbent produces like a monopolist, at stage 2. But, if there is

[3] Production may also require fixed costs. However, we assume away fixed cost of production, as it is not essential for our main story.

entry at stage 1, the firms compete like Cournot duopolists, at stage 2. We solve the game through backward induction.

Straightforward calculation shows that entry occurs at stage 1 provided

$$\frac{(a-2c)^2}{9} > E.^4 \tag{2}$$

Welfare, which is the summation of industry profit and consumer surplus, under entry is

$$W_{nl}^{e} = \frac{(a+c)^2}{9} + \frac{(a-2c)^2}{9} + \frac{(2a-c)^2}{18} - E. \tag{3}$$

But, if firm 2 does not enter, welfare is

$$W^{m} = \frac{3a^2}{8}. \tag{4}$$

The comparison of (3) and (4) shows that entry is beneficial for the society provided

$$\frac{(a+c)^2}{9} + \frac{(a-2c)^2}{9} + \frac{(2a-c)^2}{18} - \frac{3a^2}{8} \equiv X > E. \tag{5}$$

It must be noted that the value of X is negative if $c \in (\frac{5a}{22}, \frac{a}{2})$, which shows that Klemperer (1988) and Lahiri and Ono (1988), where welfare may reduce due to higher competition or lower marginal cost of the relatively high cost firm, respectively, are the special cases of our analysis.

Proposition 1: *Entry is excessive for* $E \in (Max\{0, X\}, \frac{(a-2c)^2}{9})$.

Proof: See Appendix A. Q.E.D.

[4] We assume that firm 2 enters if and only if it earns net positive profit under entry. So, entry does not occur for $\frac{(a-2c)^2}{9} \leq E$.

So, if the entrant is technologically inferior to that of the incumbent, we find that there is no insufficient entry without licensing.

2.2 Entry with licensing

Now, consider licensing in the analysis of the previous section. We consider the following game with licensing. At stage 1, the entrant decides on entry. At stage 2, the firms decide on licensing. At stage 3, the firms produce like Cournot duopolists if entry occurs at stage 1. If there is no entry at stage 1, the incumbent produces like a monopolist. We solve the game through backward induction.

2.2.1 Profitability of licensing

It is trivial that if there is no entry at stage 1, firm 1 is monopolist and there will be no licensing at stage 2. So, licensing occurs only if there is entry at stage 1.

Let us now analyze when licensing is profitable, conditional on entry at stage 1. Following Katz and Shapiro (1985), Marjit (1990), Mukherjee (2002) and many others, we assume that, in case of licensing, firm 1 licenses its technology to firm 2 against an up-front fixed-fee, F.[5] However, the fixed-fee is determined through generalized Nash bargaining process.[6]

[5] We consider the fixed-fee licensing contract in order to show the result of this paper in the simplest possible way. This modeling strategy also helps us to show that licensing can reduce welfare even if it does not consist of output royalty. Non-infringing imitation or 'inventing around' by the licensee or lack of information needed for the provision of royalty in the licensing contract could be the reason for licensing with up-front fixed-fee only (see, e.g., Katz and Shapiro, 1985 and Rockett, 1990). It would be clear from our working paper Mukherjee and Mukherjee (2003) that the main results of this paper hold even for licensing with per-unit royalty. The main difference we get between the fixed-fee licensing and the royalty licensing is that, licensing does not occur always (occurs always) in the former (latter) situation.

[6] See, e.g., Mukherjee (2002) and Mukherjee and Mukherjee (2002) for other works on licensing where price of the technology is determined through bargaining.

The assumption of fixed-fee licensing enables both firms to produce with the constant marginal cost of production 0 under licensing.[7] So, if licensing occurs, profits of firms 1 and 2 in the product market are $\frac{a^2}{9}+F$ and $\frac{a^2}{9}-F$ respectively. However, while bargaining for the fixed-fee, the payoffs of firms 1 and 2 under no licensing provide the respective reservation payoffs. Since licensing occurs after entry, the cost of entry does not affect the decision on licensing, and therefore, the reservation payoffs of firms 1 and 2 are respectively $\frac{(a+c)^2}{9}$ and $\frac{(a-2c)^2}{9}$.

So, the fixed-fee, F, is determined by maximizing the following expression:

$$\underset{F}{Max}\left(\frac{a^2}{9}+F-\frac{(a+c)^2}{9}\right)^{\alpha}\left(\frac{a^2}{9}-F-\frac{(a-2c)^2}{9}\right)^{(1-\alpha)}, \tag{6}$$

where α and $(1-\alpha)$ are the bargaining powers of firms 1 and 2 respectively. Maximizing (6) and after rearranging, the optimal licensing fee is

$$F^*=\alpha\left(\frac{2a^2}{9}-\frac{(a+c)^2}{9}-\frac{(a-2c)^2}{9}\right)+\left(\frac{(a+c)^2}{9}-\frac{a^2}{9}\right) \tag{7}$$

and it increases with α and c. Second order condition for maximization is satisfied.

Therefore, the net gain from licensing to firms 1 and 2 are respectively

$$\frac{a^2}{9}-\frac{(a+c)^2}{9}+F^*=\alpha\left(\frac{2a^2}{9}-\frac{(a-2c)^2}{9}-\frac{(a+c)^2}{9}\right) \tag{8}$$

$$\frac{a^2}{9}-\frac{(a-2c)^2}{9}-F^*=(1-\alpha)\left(\frac{2a^2}{9}-\frac{(a-2c)^2}{9}-\frac{(a+c)^2}{9}\right). \tag{9}$$

[7] We assume that licensing helps firm 2 to get the full benefit of firm 1's technology.

So, licensing occurs provided $\left(\frac{2a^2}{9}-\frac{(a-2c)^2}{9}-\frac{(a+c)^2}{9}\right)>0$ or $c<\frac{2a}{5}$, and licensing has no impact on our analysis if $c>\frac{2a}{5}$. We concentrate on $c<\frac{2a}{5}$ in the following analysis.

Hence, if $c<\frac{2a}{5}$, entry occurs at stage 1 provided

$$\frac{a^2}{9}-F^*>E \Rightarrow (1-\alpha)\left(\frac{2a^2}{9}-\frac{(a-2c)^2}{9}-\frac{(a+c)^2}{9}\right)+\frac{(a-2c)^2}{9}>E. \qquad (10)$$

But, even if $c<\frac{2a}{5}$, firm 2 does not enter for

$$(1-\alpha)\left(\frac{2a^2}{9}-\frac{(a-2c)^2}{9}-\frac{(a+c)^2}{9}\right)+\frac{(a-2c)^2}{9}\le E. \qquad (11)$$

Under licensing, if entry occurs, welfare is

$$W_l^e=\frac{4a^2}{9}-E, \qquad (12)$$

while, under no entry, it is

$$W^m=\frac{3a^2}{8}. \qquad (13)$$

It is immediate from (2) and (10) that, for any positive bargaining power of firm 2, i.e., for $\alpha<1$, licensing increases its net profit compared to no licensing. Given that $c<\frac{2a}{5}$, firm 2 realizes that if it enters the market, firm 1 will license the technology to firm 2. The anticipated benefit from licensing induces firm 2 to enter the market at stage 1, which increases competition, and, in turn, encourages firm 1 to license the technology at stage 2. Therefore, if $c<\frac{2a}{5}$, licensing increases the incentive for entry, which increases with the higher bargaining power of firm 2.

2.2.2 The welfare effects of licensing

It is immediate from (12) and (13) that entry, under licensing, is beneficial for the society provided

$$\frac{5a^2}{72} > E\,. \tag{14}$$

Proposition 2: *Assume* $c < \frac{2a}{5}$ *and define* $c^*(\alpha)$ *as the own marginal cost of firm 2 at which* $\frac{5a^2}{72} = \frac{a^2}{9} - F^*$ *for a given bargaining power of firm 1 (i.e.,* α*), where* F^* *is given in (8).*

(i) Entry is excessive for any positive bargaining power of firm 2 if the own marginal cost of firm 2 is very low (i.e., $c \in (0, c^*(\alpha = 1))$*, where* $c^*(\alpha = 1) < \frac{2a}{5}$*) and* $E \in (\frac{5a^2}{72}, \frac{a^2}{9} - F^*)$.

(ii) Given the bargaining power of the firms, entry is insufficient if the own marginal cost of firm 2 is sufficiently high (i.e., $c \in (c^*(\alpha), \frac{2a}{5})$*) and* $E \in (\frac{a^2}{9} - F^*, \frac{5a^2}{72})$.

Proof: See Appendix B. Q.E.D.

Since, $\frac{5a^2}{72}$ can be greater than, less than or equal to $\frac{(a-2c)^2}{9}$, the comparison of Propositions 1 and 2 gives the effect of licensing immediately.

Proposition 3: *(i) If the own marginal cost of firm 2 is very low, licensing reduces excessive entry for* $E \in (X, Min\{\frac{5a^2}{72}, \frac{(a-2c)^2}{9}\})$*, whereas it creates excessive entry for* $E > \frac{(a-2c)^2}{9}$.

(ii) If the own marginal cost of firm 2 is very high, there is insufficient entry under licensing.

There are certain effects of licensing. Licensing may induce firm 2 to enter when entry is unprofitable otherwise. This creates higher competition. Further, whenever licensing occurs, it increases technological efficiency in the industry since both firms are able to produce with the efficient technology. Both these effects have positive impacts on welfare. However, if licensing induces entry, it imposes cost to the society due to the cost of entry and tends to reduce welfare.

If the cost of entry is such that entry occurs irrespective of licensing, licensing does not impose further cost to the society but creates the above-mentioned positive effects on welfare. In this situation, licensing reduces excessive entry.

But, if entry occurs only under licensing, all the above-mentioned effects are in force. If the own marginal cost of firm 2 is very low and yet entry is unprofitable without licensing, the entry cost must be very high and the negative effect of licensing on welfare will be sufficiently large. Even if licensing-induced entry creates higher competition and increases the cost efficiency of the entrant, the negative effect of higher entry cost outweighs the positive effects of licensing and creates excessive entry. In contrast, if the own marginal cost of firm 2 is very high and entry occurs only under licensing, the entry cost must be very low. In this situation, the positive effects of the licensing-induced entry outweigh the negative effect of the entry cost.

However, if the own marginal cost of firm 2 is very high, the fixed-fee under licensing will be very high, and will not benefit firm 2 very much from licensing. In this situation, licensing does not create much incentive for entry. Hence, if the own marginal cost of firm 2 is very high, licensing may benefit the society, if entry occurs, whereas it does not create enough incentive for entry, and so, creates insufficient entry.

2.2.3 The effects of bargaining power

Figure 1 considers excessive entry under licensing and shows the implications of higher bargaining power of firm 2.

Figure 1

If there is no licensing, excessive entry occurs for $E \in (X, \frac{(a-2c)^2}{9})$, whereas excessive entry, under licensing, occurs for $E \in (\frac{5a^2}{72}, (\frac{a^2}{9} - F^*)^0)$, when the bargaining power of firm 1 is α^0. If the bargaining power of firm 1 reduces from α^0 to α^1, excessive entry occurs for $E \in (\frac{5a^2}{72}, (\frac{a^2}{9} - F^*)^1)$, which immediately implies that here higher bargaining power of firm 2 increases the possibility of welfare reducing licensing. Further, it is clear from Proposition 2(i) that there is excessive entry under licensing if the own marginal cost of firm 2 is very low. Therefore, higher bargaining power of firm 2 increases the possibility of welfare reducing licensing if the own marginal cost of firm 2 is very low.

Figure 2 considers the case where entry is insufficient under licensing.

Figure 2

If there is no licensing, excessive entry occurs for $E \in (X, \frac{(a-2c)^2}{9})$, whereas insufficient entry, under licensing, occurs for $E \in ((\frac{a^2}{9} - F^*)^0, \frac{5a^2}{72})$, when the bargaining power of firm 1 is α^0. If the bargaining power of firm 1 reduces from α^0 to α^1, insufficient entry occurs for $E \in ((\frac{a^2}{9} - F^*)^1, \frac{5a^2}{72})$, which immediately implies that here higher bargaining power of firm 2 increases the possibility of welfare increasing licensing. Further, it is clear from Proposition 2(ii) that there is insufficient entry under licensing if the own marginal cost of firm 2 is very high. Therefore, higher bargaining power of firm 2 increases the possibility of welfare increasing licensing if the own marginal cost of firm 2 is very high.

Lastly, Figure 3 considers the case of both insufficient and excessive entry under licensing, which may occur when $c \in (c*(\alpha = 1), c^*(\alpha = 0))$.

Figure 3

Figure 3 is similar to Figure 2 with the exception that insufficient entry occurs for $E \in ((\frac{a^2}{9} - F^*)^0, \frac{5a^2}{72})$, when the bargaining power of firm 1 is α^0, but excessive entry occurs for $E \in (\frac{5a^2}{72}, (\frac{a^2}{9} - F^*)^1)$, when the bargaining power of firm 1 reduces to α^1. So, higher bargaining power of firm 2 increases welfare due to licensing if $E \in ((\frac{a^2}{9} - F^*)^0, \frac{5a^2}{72})$, but it reduces welfare due to licensing if $E \in (\frac{5a^2}{72}, (\frac{a^2}{9} - F^*)^1)$.

The following proposition summarizes the above discussion.

Proposition 4: *Higher bargaining power of firm 2 increases the possibility of lower (higher) welfare due to licensing if its own marginal cost is very low (high). But, for intermediate own marginal cost of firm 2, whether higher bargaining power of firm 2 increases the possibility of higher or lower welfare due to licensing is ambiguous and depends on the cost of entry.*

The reason for the above result is as follows. If the own marginal cost of firm 2 is very low and licensing induces entry only under relatively higher bargaining power of firm 2, the higher bargaining power of firm 2 imposes sufficiently high cost of entry to the society, which helps to reduce welfare. But, if the own marginal cost of firm 2 is very high and licensing induces entry only under relatively higher bargaining power of firm 2, the cost to the society is very small. In this situation, higher bargaining power of firm 2 helps to increase welfare by attracting entry. If the own marginal cost of firm 2 is moderate and higher bargaining power of firm 2 induces entry, entry does not impose very high cost on the society but helps to increase competition in the market. As a result, entry under higher bargaining power of firm 2 increases (reduces) welfare for relatively low (high) entry cost.

3. Entry of a technologically superior firm

3.1 Entry without licensing

Let us now consider the situation where the incumbent (firm 1) is technologically inferior to that of the entrant (firm 2). As mentioned in the introduction, this may happen when there is technological leapfrogging by the entrant. We assume that firm 1 produces the product with the constant marginal cost of production c, whereas firm

2's marginal cost of production is 0. However, firm 2 needs to bear the entry cost, $E > 0$. We also assume that $c < \frac{a}{2}$, which will always generate duopoly under entry.

Firm 2 enters the market if and only if

$$\frac{(a+c)^2}{9} > E. \tag{15}$$

If entry occurs, welfare is given by

$$W_{nl}^{e} = \frac{(a+c)^2}{9} + \frac{(a-2c)^2}{9} + \frac{(2a-c)^2}{18} - E. \tag{16}$$

But, if firm 2 does not enter, welfare is

$$W^{m} = \frac{3(a-c)^2}{8}. \tag{17}$$

So, entry is beneficial for the society provided

$$\frac{(a+c)^2}{9} + \frac{(a-2c)^2}{9} + \frac{(2a-c)^2}{18} - \frac{3(a-c)^2}{8} \equiv G > E. \tag{18}$$

Proposition 5: *Entry is excessive if* $c \in (0, \frac{a}{3})$ *and* $E \in (G, \frac{(a+c)^2}{9})$. *But, entry is insufficient if* $c \in (\frac{a}{3}, \frac{a}{2})$ *and* $E \in (\frac{(a+c)^2}{9}, G)$.

Proof: See Appendix C. Q.E.D.

In contrast to Proposition 1, where the incumbent is technologically superior to that of the entrant, the above result shows that there may be insufficient entry without licensing if the incumbent is technologically inferior to that of the entrant.

3.2 Entry with licensing

Let us now consider the possibility of licensing. Like section 2, we focus on the fixed-fee licensing.

We consider the following game. At stage 1, firm 2 decides whether to license the technology or not. At stage 2, firm 2 decides whether to enter the market or not. At stage 3, production takes place and the profits are realized.

It must be noted that the moves of the game in this section is different from that of subsection 2.2. Since, firm 2 (the entrant) is the licenser in this section, it must be clear that it would be natural to consider the licensing decision before entry for two reasons. First, if there is no licensing, firm 2 should have the option to enter the market. Second, the licensing decision before entry may prevent entry of firm 2 by making firm 1 more cost efficient, which will increase the industry profit and the surplus from licensing.

To do the analysis in the simplest way, we also assume that the licenser (firm 2) has full bargaining power. Since licensing decision is taken before the entry decision, it should be clear that the licensing fee, which depends on the bargaining power of the firms, does not affect the entry decision. Therefore, the results of this section will not be affected by different bargaining power of the firms.

Under licensing, firm 2 enters the market if and only if

$$\frac{a^2}{9} > E. \tag{19}$$

Therefore, firm 1 will be a monopolist under licensing when $\frac{a^2}{9} < E$, which implies that, in this situation, licensing will occur for all cost differences between the firms.

Since entry occurs after licensing when $\frac{a^2}{9} > E$, licensing occurs in this situation provided the industry profit is higher under licensing than no licensing. Following the analysis of subsection 2.2.1, we find that licensing occurs for $c < \frac{2a}{5}$. Hence, if $\frac{a^2}{9} > E$, we will concentrate our attention to $c < \frac{2a}{5}$; otherwise, licensing will have no impact in this situation.

Under licensing, if entry occurs welfare is

$$W_l^e = \frac{4a^2}{9} - E, \tag{20}$$

but, if entry does not occur, welfare is

$$W_l^m = \frac{3a^2}{8}. \tag{21}$$

So, entry is beneficial for the society provided

$$\frac{8a^2}{18} - \frac{3a^2}{8} = \frac{5a^2}{72} > E. \tag{22}$$

Since, $\frac{5a^2}{72} < \frac{a^2}{9}$, which gives the following result immediately.

Proposition 6: *Under licensing, entry is excessive for* $E \in (\frac{5a^2}{72}, \frac{a^2}{9})$.

So, while technology licensing eliminates the insufficient incentive for entry that may occur under no licensing, there is still the possibility of excessive entry. The following proposition shows the effect of licensing on the incentive for entry.

Proposition 7: *(i) If the own marginal cost of firm 1 is not very small, i.e.,* $c > \frac{(-11+2\sqrt{43})}{17}$*, technology licensing creates excessive entry for relatively low entry costs, but it eliminates excessive or insufficient entry that occurs without licensing.*

(ii) If the own marginal cost of firm 1 is very small, i.e., $c < \frac{(-11+2\sqrt{43})}{17}$*, technology licensing creates excessive entry for relatively low entry costs, while it reduces (but does not completely eliminate) excessive entry that occurs without licensing.*

Proof: See Appendix D. Q.E.D.

The reason for the above result is as follows. If there is licensing, it reduces the incentive for entry compared to no licensing by making the incumbent more cost efficient. Thus, licensing reduces entry for relatively high entry costs, which, in turn, eliminates the possibility of either excessive or insufficient entry for those high entry costs. However, since technology licensing occurs even under no entry and makes the incumbent more cost efficient, it reduces the social benefit of entry, though it keeps the incentive for entry for relatively low entry costs. As a result, excessive entry occurs under licensing for relatively low entry costs.

As a final remark, it is clear from Propositions 2 and 6 that, though excessive entry may occur under licensing irrespective of the technological superiority of the incumbent, excessive entry is more likely when the entrant is technologically superior to that of the incumbent. Further, if the entrant is technologically inferior to that of the incumbent and entry is insufficient under licensing, entry, for those entry costs, is

both privately and socially beneficial under licensing if the entrant is technologically superior to that of the entrant.

4. Concluding remarks

We show the welfare effects of entry in presence of licensing, and consider the situations for technologically superior and technologically inferior entrants. We find that technology licensing has significant effects on the incentive for entry.

If the entrant is technologically inferior to that of the incumbent, we show that while licensing reduces (or completely eliminates) excessive entry for relatively low entry costs, it creates excessive entry for those entry costs at which entry does not occur without licensing. We also show that there may even insufficient entry under licensing, whereas insufficient entry does not occur without licensing. Whether licensing creates either excessive or insufficient entry depends on the own marginal cost of the entrant and its bargaining power. We find that whether higher bargaining power of the entrant increases the possibility of welfare increasing licensing is ambiguous.

If the entrant is technologically superior to that of the incumbent, we show that there is no insufficient incentive for entry under licensing, though it may occur without licensing. While licensing creates excessive entry for relatively low entry costs, it eliminates excessive entry for relatively high entry costs that occurs without licensing. Hence, the factors such as the cost of entry, the marginal cost difference between the firms, the bargaining power of the firms, and the technological superiority of the incumbent or the entrant are important for estimating the welfare effects of licensing.

Appendix

A Proof of Proposition 1: Straightforward calculation shows that $X < \frac{(a-2c)^2}{9}$. Since X can be either positive or negative depending on c, entry is excessive from the society's point of view if $E \in (Max\{0, X\}, \frac{(a-2c)^2}{9})$. Q.E.D.

B Proof of Proposition 2: The fixed-fee, F^*, is continuous and positively related to the bargaining power of firm 1, α. Given the value of c, $\frac{a^2}{9} - F^*$ reaches the minimum at $\alpha = 1$. We find that, if $\alpha = 1$, $\frac{a^2}{9} - F^* \underset{<}{\geq} \frac{5a^2}{72}$ when $3a^2 - 32ac + 32c^2 \underset{<}{\geq} 0$ or $c \underset{>}{\leq} c^*(\alpha = 1)$, where $3a^2 - 32ac + 32c^2 = 0$ at $c^*(\alpha = 1)$. Since, $c^*(\alpha)$ increases with lower α, this proves the part (i) of the proposition.

It is easy to check that, for a given $\alpha \in [0,1]$, there exists $c^*(\alpha) \in (0, \frac{2a}{5})$ at which $\frac{a^2}{9} - F^* = \frac{5a^2}{72}$, and $\frac{a^2}{9} - F^* < \frac{5a^2}{72}$ for $c \in (c^*(\alpha), \frac{2a}{5})$, which proves the part (ii) of the result. Q.E.D.

C Proof of Proposition 5: We find that $G \underset{<}{\geq} \frac{(a+c)^2}{9}$ if and only if $c \underset{<}{\geq} \frac{a}{3}$. Hence, entry is excessive if $c \in (0, \frac{a}{3})$ and $E \in (G, \frac{(a+c)^2}{9})$. But, entry is insufficient if $c \in (\frac{a}{3}, \frac{a}{2})$ and $E \in (\frac{(a+c)^2}{9}, G)$. Q.E.D.

D Proof of Proposition 7: We find that $G > \frac{5a^2}{72}$, but $G > (<) \frac{a^2}{9}$ for $c > (<) \frac{(-11 + 2\sqrt{43})}{17}$. The rest of proof follows immediately from the comparison of Propositions 5 and 6. Q.E.D.

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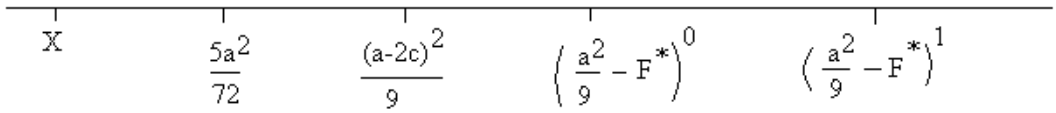

Figure 1: Excessive entry under licensing

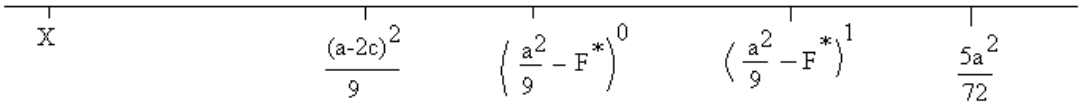

Figure 2: Insufficient entry under licensing

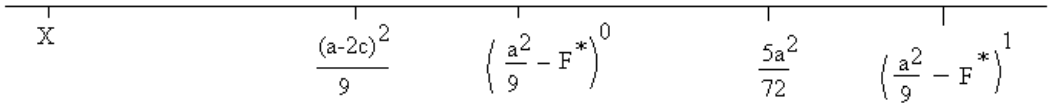

Figure 3: Insufficient and excessive entry under licensing