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MULTI-MARKET COMPETITION, R&D, AND WELFARE IN OLIGOPOLY

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Multi-market competition, R&D, and welfare in oligopoly*

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Abstract

We investigate a multi-market Cournot model with strategic process R&D investments wherein a multi-market monopolist meets entrants that enter one of the markets. We find that entry can enhance the total R&D expenditure of the incumbent firm. That is, entry can stimulate R&D effort. Moreover, the incumbent's profit *nonmonotonically* changes as the number of entrants increases. Depending on the fixed entry costs and R&D technologies, both insufficient and excess entry can appear.

JEL classification: L13, O32, L11

Key words: multi-market, oligopoly, process R&D, entry, welfare

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1 Introduction

Asymmetric competition between multi-product firms and single-product firms is commonly observed. In the retail industry, nationwide retailers (Walmart, Metro, etc.) compete with local retailers in each region. In the airline industry, network carriers operating multiple routes compete with regional carriers or low-cost carriers on certain routes. In the vehicle industry, automobile (cars, buses, and trucks) producers compete with some automakers that specialize in the production of cars. In those industries, multi-product firms can have competitive advantages relative to their competitors because of their product multiplicities. This is because those multi-product firms are able to apply their technologies to multiple production lines. In addition, because those firms apply the outcomes of R&D to their products, their returns from R&D are greater, and the multiplicities of products can generate competitive advantages.[1] Given these observations, this paper investigates how market entry affects the multi-product firms' process R&D and profits, as well as how social welfare is influenced.

The basic model structure is as follows. An incumbent provides a product (call it A). Rival firms can also produce product A. The incumbent also provides another product (call it B). No potential entrants can supply product B. In other words, the incumbent is the monopolist in market B. There are several possible reasons why no entrant produces product B. For instance, product B includes advanced technologies that are available only to the incumbent. Potential entrants do not have sufficient skills to use those advanced technologies and/or those technologies are patented by the monopolist. Another reason is that market B is regulated by governmental authorities. For instance, this is because the incumbent engages in lobbying activities to protect market B.

Unlike the result that is expected in a standard Cournot model (i.e., an entry will diminish

[1] The standard model of strategic R&D is formulated by Brander and Spencer (1983), and the literature dealing with strategic R&D competition is now fairly abundant (Spence, 1984; d'Aspremont and Jacquemin, 1988; Suzumura, 1992; Lahiri and Ono, 1999; and Kitahara and Matsumura, 2006).

the incumbent's incentive to engage in R&D investment), we first show that entry can enhance the total R&D expenditure of the incumbent if the level of the incumbent's cost-reducing technology is higher than a threshold level. Note that the threshold level *can be lower* than the levels of the entrants' cost-reducing technologies. That is, even though the cost-reducing technology of the incumbent is inferior to that of entrants, entry can stimulate the incumbent's R&D. We now discuss the intuition behind the result. On the one hand, entry in market A steals the incumbent's quantity supplied and weakens its incentive to engage in R&D. The existence of market B, however, allows the incumbent to maintain its total quantity supplied because entry only occurs in market A. This high level of supply maintains the incumbent's incentive for cost-reducing R&D efforts. On the other hand, there exists a strategic effect of entry in which the R&D effort reduces the entrant's quantity, which benefits the incumbent by raising the price. The strategic effect can dominate the decrease in the quantity supplied in market A. As a result, the incumbent enhances its R&D efforts following entry.

Moreover, we find that the incumbent's profit nonmonotonically changes as the number of entrants increases. Specifically, an additional entry increases the incumbent's profit when the number of existing entrants is large. As described in the first result, entry can accelerate the R&D incentive of the incumbent. This implies that entry can be used as a credible commitment of the incumbent to invest more. This commitment diminishes the incentives of entrants to invest. Because the strategic effect is related to the entrants' reactions, as the number of entrants increases, the strategic effect mentioned above is stronger. This is why an additional entry can increase the incumbent's profit when the number of existing entrants is large.

Concerning a single product market, Ishida et al. (2010) show that entry of inefficient firms can stimulate cost-reducing R&D by the efficient incumbent firm. Moreover, entry of inefficient firms can enhance the profit of the incumbent firm if the incumbent's *ex ante* marginal cost is small enough.[2] That is, a significant cost advantage of the incumbent is the driving force that enhances the profit of the incumbent by entry. It is noteworthy here that our property is quite different from that in Ishida et al. (2010). Our model assumes that the cost-reducing technology of the incumbent in itself can be inferior to those of potential entrants, whereas Ishida et al. (2010) assume that the incumbent has a superior *ex ante* marginal cost.[3] Adding our new results, we can say that the difference in *ex ante* marginal costs plays an important role in inducing aggressive R&D investments by the incumbent in a single market case; however, such a difference is not necessarily important in a multi-product market.

Our analysis on social welfare focuses on the effect of entry. In the previous papers dealing with the entry problem, excess entry always happens in the standard Cournot models (e.g., Mankiw and Whinston, 1986; Suzumura and Kiyono, 1987). Moreover, Okuno-Fujiwara and Suzumura (1993) show that the excess entry theorem holds even when symmetric firms in the single product market engage in cost-reducing R&D investments. The main reason is the business-stealing effects of entry. Our paper also finds that the first entry tends to enhance consumer welfare although it is excessive from the viewpoint of social welfare. However, excess entry does not always hold under free entry. We show that depending on fixed entry costs and R&D technologies, both insufficient and excess entry can appear. When the fixed entry costs are small and the incumbent firm's R&D technology is not so inefficient when

[2] Several recent studies have discussed instances where an increase in the number of firms may actually increase firm profit. Coughlan and Soberman (2005), Chen and Riordan (2007), and Ishibashi and Matsushima (2009) belong to this line of research, but the underlying mechanism of our model differs substantially from theirs. In these previous studies, market entry works as a commitment device to soften market competition, so that the market actually becomes less competitive as it is entered by more firms. Moreover, those papers do not include R&D investments. Using vertical relationships between upstream and downstream firms, Tyagi (1999), Pack and Saggi (2001) and Mukherjee et al. (2009) show that entry can enhance the profits of incumbents. Using asymmetric Stackelberg oligopoly models, Pal and Sarkar (2001) and Mukherjee and Zhao (2009) show the possibilities of increases in existing firms' profits by entry. In the two papers, asymmetry among the firms is a key factor in deriving their main result, whereas the main mechanism in deriving ours is quite different.

[3] In Ishida et al. (2010), similar results can be derived even when the incumbent has a superior cost-reducing technology given that the *ex ante* marginal costs of entrants and the incumbent are common.

compared with those of entrants, market entry is insufficient from the viewpoint of social welfare. This is because entry of new firms can enhance the incumbent's R&D investment in our model, while entry always diminishes R&D investment in Okuno-Fujiwara and Suzumura (1993). When the incumbent's R&D technology is efficient, this effect is strong and then its market share becomes large. In this situation, the incumbent's R&D should be stimulated by entry from the viewpoint of social welfare. However, the incumbent's stronger incentive for R&D diminishes the profitability of each entrant and then it deters entry. Consequently, entry is insufficient.

Several papers have already shown market structures in which insufficient entry appears in equilibrium. Anderson and Engers (2001), Matsumura and Okamura (2006), and Gu and Wenzel (2009) investigate equilibrium entry in spatial models a la Vickrey (1964, 1999) and Salop (1979). Mukherjee and Mukherjee (2008) investigate a Cournot model with licensing. Schmidt (2009) investigates vertical differentiation models. Ghosh and Morita (2007a,b) and Mukherjee et al. (2009) take into account vertical relationship. Those papers do not consider R&D investments in oligopoly.

The remainder of this paper is organized as follows. Section 2 presents the model. Section 3 derives the outcomes of the monopoly and duopoly cases to nvestigate the effects of strategic R&D investments by the first entry. Section 4 deals with the oligopoly case. Section 5 concludes the paper.

2 Multi-product Monopolist and Entrants

A multi-product monopolist exists. It produces two products, A and B. Product A is produced with a standard technology that is also available to potential entrants (we explain entry of those entrants later). Product B is produced with the standard technology and an advanced technology that is not available to potential entrants. For instance, the advanced technology is patented by the incumbent monopolist. As a result, potential entrants cannot produce product B. In other words, the incumbent operates as a monopolist of product B.[4]

For the products, the inverse demand functions are assumed as follows:

$$p_A = 1 - Q_A, \quad p_B = 1 - Q_B,$$

where p_i is the price of product i and Q_i is the total quantity of product i ($i = A, B$).

We now assume that there are n entrants in market A (we discuss the case in which n is endogenously determined in Section 4). The incumbent and the n entrants are able to engage in cost-reducing investments related to the standard technology. Assume that c is an initial common constant marginal cost. When the incumbent (I)/an entrant (E) engages in cost-reducing R&D, it reduces its marginal cost from c to $c - e_i$ ($i = I, E$) and incurs the investment cost $k_i e_i^2$, where e_i is the R&D effort level of i and k_i is a positive constant ($i = I, E$). To simplify the analysis, we assume that $k_I = k > k_E = 1$ and $k > 3/2$. The assumption $k > 3/2$ ensures that each entrant supplies a positive quantity for any n (even when $k < 3/2$, our main results hold). That is, each entrant has a more efficient cost-reducing technology than the incumbent. For instance, entrants can concentrate their efforts toward the cost reductions concerning the standard technology whereas the incumbent has to put its effort toward both the standard and the advanced technologies.

The profit of the incumbent is

$$\pi_I = \left(1 - q_{AI} - \sum_{i=1}^{n} q_{Ei} - (c - e_I)\right) q_{AI} + (1 - q_{BI} - (c - e_I))q_{BI} - ke_I^2, \tag{1}$$

where q_{jI} is the quantity supplied by the incumbent in market j ($j = A, B$), and q_{Ei} is the quantity supplied by entrant i in market A ($i = 1, 2, \ldots, n$).

The profit of entrant i is

$$\pi_{Ei} = \left(1 - q_{AI} - q_{Ei} - \sum_{j \neq i} q_{Ej} - (c - e_{Ei})\right) q_{Ei} - e_{Ei}^2. \tag{2}$$

[4] For expositional simplicity, we assume that only one firm supplied its products to the two markets. This assumption is not essential to derive our main results.

We consider two cases: (i) the incumbent is a monopolist; and (ii) entrants also produce product A. We consider the following two-stage game. First, the firm(s) simultaneously set(s) the effort level(s) e_I and e_{Ei} ($i = 1, 2, \ldots, n$). Second, the firm(s) simultaneously set(s) the quantities supplied q_{jI} ($j = A, B$) or q_{Ei} ($i = 1, 2, \ldots, n$). The solution concept is a subgame perfect Nash equilibrium.

3 Equilibrium: Monopoly and Duopoly

We first show the results under the cases of monopoly and duopoly. In Section 4, we show the results under the cases of oligopoly and free entry.

3.1 Monopoly

We first solve the monopoly case to provide a comparison between the monopoly and the duopoly cases.

Given e_I, the quantities supplied by the incumbent are

$$q_{AI} = q_{BI} = \frac{1 - c + e_I}{2}.$$

In the first stage, the incumbent determines e_I. The first-order condition is

$$\frac{\partial \pi_I}{\partial e_I} = \frac{2(1-c) - 2(2k-1)e_I}{2} = 0.$$

This leads to

$$e_I^M = \frac{1-c}{2k-1}.$$

The quantities supplied and the profit are

$$q_{AI}^M = q_{BI}^M = \frac{(1-c)k}{2k-1}, \quad \pi_I^M = \frac{(1-c)^2 k}{2k-1}.$$

The consumer surplus and the social surplus are

$$CS^M = \frac{(1-c)^2 k^2}{(2k-1)^2}, \quad SW^M = \frac{(1-c)^2 k(3k-1)}{(2k-1)^2}.$$

3.2 Duopoly

We solve the duopoly case. We compare this case with the monopoly case discussed above.

Given e_I and e_E (we omit "1" from "E1"), the quantities supplied by the incumbent and the entrant are

$$q_{AI} = \frac{1-c+2e_I-e_E}{3}, \quad q_{BI} = \frac{1-c+e_I}{2}, \quad q_E = \frac{1-c+2e_E-e_I}{3}.$$

In the first stage, the incumbent determines e_I and the entrant determines e_E. The first-order conditions are

$$\begin{aligned}\frac{\partial \pi_I}{\partial e_I} &= \frac{17(1-c)-(36k-25)e_I-8e_E}{18}=0,\\ \frac{\partial \pi_E}{\partial e_E} &= \frac{2(2(1-c)-5e_E-2e_I)}{9}=0.\end{aligned}$$

The first-order conditions lead to

$$e_I^D = \frac{23(1-c)}{60k-47}, \quad e_E^D = \frac{4(6k-7)(1-c)}{60k-47}.$$

The quantities supplied by the incumbent and the entrant are

$$q_{AI}^D = \frac{3(1-c)(4k+3)}{60k-47}, \quad q_{BI}^D = \frac{6(1-c)(5k-2)}{60k-47}, \quad q_E^D = \frac{6(1-c)(6k-7)}{60k-47}.$$

The profits of the incumbent and the entrant are

$$\pi_I^D = \frac{(1-c)^2(1044k^2-1033k+225)}{(60k-47)^2}, \quad \pi_E^D = \frac{20(1-c)^2(6k-7)^2}{(60k-47)^2}.$$

The consumer surplus and the social surplus are

$$SW^D = \frac{(1-c)^2(6732k^2-9314k+3643)}{2(60k-47)^2}, \quad CS^D = \frac{9(1-c)^2(356k^2-432k+137)}{2(60k-47)^2}.$$

Quantity We now briefly discuss the quantities supplied by the firms. By entry, the quantities supplied by the incumbent are changed as follows: (i) $q_{AI}^M > q_{AI}^D$, (ii) $q_{BI}^M \le q_{BI}^D$ iff $k \le 12/7$. The inequality (i) reflects the fact that competition reduces the quantity. The reason why the inequality (ii) holds is that the incumbent's R&D effort can be stimulated by entry. In market A, the difference between the quantities supplied by the incumbent and the entrant is as follows: $q_{AI}^D - q_E^D \leq 0$ iff $k \geq 17/8$. If the entrant's cost-reducing technology is highly efficient, it produces more than the incumbent. These discussions can be applied also to the oligopoly case in the next section.

An entry and R&D effort We now compare the R&D efforts of the incumbent in the two cases. The difference between the R&D efforts is

$$e_I^D - e_I^M = \frac{2(1-c)(12-7k)}{(2k-1)(60k-47)}. \tag{3}$$

From the equation, we have the following proposition.

Proposition 1 *The incumbent's investment level under duopoly is larger than that under monopoly if and only if $k < 12/7$.*

That is, if the cost-reducing technology of the incumbent is not so inefficient, an entry enhances the R&D incentive of the incumbent.

We now explain the mechanism behind Proposition 1. The effect of the investment on the incumbent's profit is written as

$$\frac{\partial \pi_I^D}{\partial e_I} = \underbrace{p'_A q_{AI}^D \frac{\partial q_E^D}{\partial e_I}}_{\text{strategic-effect}} + \underbrace{(q_{AI}^D + q_{BI}^D) - I'(e_I)}_{\text{cost-reducing effect}},$$

where $I(\cdot)$ is the investment cost of the incumbent. The cost-reducing effect is based on the total quantity supplied by the incumbent. The total quantity decreases because of the entry. This decrease diminishes the incentive to engage in R&D. The strategic effect consists of two elements: one is that a reduction in the rivals' quantities leads to an increase in the price; the other is that the benefit from an increase in the price is proportional to its own quantity in market A. The first element is not correlated to the value of k, but the second is indirectly correlated to the value of k because q_{AI}^D is related to the value of k. That is, when k is small (the cost-reducing technology of the incumbent is not so inefficient), the strategic effect becomes significant. To sum up, the entry enhances the strategic effect whereas it diminishes the cost-reducing effect.

Figure 1 summarizes the explanation. On the one hand, the decrease in the cost-reducing effect lowers the incumbent's marginal benefit of investment. On the other hand, the strategic effect enhances the incumbent's marginal benefit of investment. Therefore, the marginal benefit function under the duopoly case (MB^D in the figure) is steeper than that under the monopoly case (MB^M) because there is no strategic effect in the monopoly case. Depending on the value of k, the entry effect on R&D is determined.

[**Figure 1 here**]

This property is quite different from Ishida et al. (2010) who also show the investment-enhancing effect of entry. Our model assumes that the cost-reducing technology of the incumbent in itself is inferior to those of potential entrants, whereas Ishida et al. (2010) assume that the incumbent has a superior production technology.

An entry and welfare The entry tends to enhance consumer welfare although it is excessive from the viewpoint of social welfare (see Figure 2). The increment in consumer (social) welfare is larger (smaller) than the profit of the entrant. This is because the entry can increase the incentives of R&D investments and decreases the market price of product A. The duplication of the R&D investments is wasteful from the viewpoint of social welfare. This is significant when k is small (the incumbent's marginal investment cost is small). This logic, however, does not always hold when the number of entrants is endogenously determined.

[**Figure 2 here**]

4 Equilibrium: Oligopoly and Free Entry

We first consider an entry in the case where n entrants exist in market A. Next, we investigate welfare under free entry in market A.

Given e_I and e_{Ei} $(i = 1, 2, \dots, n)$, the quantities supplied by the incumbent and the entrants are

$$q_{AI} = \frac{1 - c + (n+1)e_I - \sum_{i=1}^{n} e_{Ei}}{n+2}, \quad q_{BI} = \frac{1 - c + e_I}{2},$$
$$q_{Ei} = \frac{1 - c + (n+1)e_{Ei} - e_I - \sum_{j \neq i} e_{Ej}}{n+2}.$$

In the first stage, the incumbent determines e_I and each entrant determines e_{Ei} $(i = 1, 2, \dots, n)$. The first-order conditions are

$$\frac{\partial \pi_I}{\partial e_I} = \frac{(1-c)(n^2+8n+8) - (4(n+2)^2 k - (5n^2+12n+8))e_I - 4(n+1)\sum_{i=1}^{n} e_{Ei}}{2(n+2)^2} = 0,$$
$$\frac{\partial \pi_{Ei}}{\partial e_{Ei}} = \frac{2((1-c)(n+1) - (2n+3)e_{Ei} - (n+1)e_I - (n+1)\sum_{j \neq i} e_{Ej})}{(n+2)^2} = 0.$$

The first-order conditions lead to

$$e_I^O = \frac{(1-c)(n^3+4n^2+10n+8)}{4(n+2)(n^2+2n+2)k - (5n^3+16n^2+18n+8)},$$
$$e_{Ei}^O = \frac{2(1-c)(n+1)(2(n+2)k - (3n+4))}{4(n+2)(n^2+2n+2)k - (5n^3+16n^2+18n+8)}.$$

The quantities supplied by the incumbent and the entrants are

$$q_{AI}^O = \frac{(1-c)(n+2)(4k + n(n+2))}{4(n+2)(n^2+2n+2)k - (5n^3+16n^2+18n+8)},$$
$$q_{BI}^O = \frac{2(1-c)(n+2)((n^2+2n+2)k - n(n+1))}{4(n+2)(n^2+2n+2)k - (5n^3+16n^2+18n+8)},$$
$$q_{Ei}^O = \frac{2(1-c)(n+2)(2(n+2)k - (3n+4))}{4(n+2)(n^2+2n+2)k - (5n^3+16n^2+18n+8)}.$$

The profits of the incumbent and the entrants are

$$\begin{aligned}\pi_I^O = & \frac{(1-c)^2(n+2)^2(4k+n(n+2))^2}{(4(n+2)(n^2+2n+2)k - (5n^3+16n^2+18n+8))^2} \\ & + \frac{4(1-c)^2(n+2)^2((n^2+2n+2)k - n(n+1))^2}{(4(n+2)(n^2+2n+2)k - (5n^3+16n^2+18n+8))^2} \\ & - \frac{(1-c)k(n^3+4n^2+10n+8)^2}{(4(n+2)(n^2+2n+2)k - (5n^3+16n^2+18n+8))^2},\end{aligned}$$
$$\pi_{Ei}^O = \frac{4(1-c)^2(2n+3)(2(n+2)k - (3n+4))^2}{(4(n+2)(n^2+2n+2)k - (5n^3+16n^2+18n+8))^2}.$$

The social surplus and consumer surplus are

$$
\begin{aligned}
CS^O =& \frac{(1-c)^2(n+2)^2(4(n+1)^2k-(5n+6)n)^2}{2(4(n+2)(n^2+2n+2)k-(5n^3+16n^2+18n+8))^2} \\
&+ \frac{2(1-c)^2(n+2)^2((n^2+2n+2)k-(n+1)n)^2}{(4(n+2)(n^2+2n+2)k-(5n^3+16n^2+18n+8))^2}, \\
SW^O =& CS^O + \pi_I^O + n\pi_{Ei}^O.
\end{aligned}
$$

An entry and R&D effort As explained in the previous section, an increase in n can stimulate the R&D efforts of the incumbent. The partial derivative of e_I^O with respect to n is

$$
\frac{\partial e_I^O}{\partial n} = \frac{4(1-c)[(n^4+16n^3+46n^2+48n+16)-4(2n^3+7n^2+8n+2)k]}{(4(n+2)(n^2+2n+2)k-(5n^3+16n^2+18n+8))^2}. \tag{4}
$$

From the equation, we have the following proposition.

Proposition 2 *The incumbent's investment level is increasing in n if and only if*

$$
k < \frac{n^4+16n^3+46n^2+48n+16}{4(2n^3+7n^2+8n+2)}.
$$

This is summarized in Figure 3. For any $n \geq 1$, the right-hand side is increasing in n. When $n = 1$, this is $127/76 \simeq 1.671$.[5] The reason why the inequality holds is similar to that in the previous section.

[Figure 3 here]

Entry and the profit of the incumbent The partial derivative of the incumbent's profit is

$$
\begin{aligned}
\frac{\partial \pi_I^O}{\partial n} =& -\frac{16(1-c)^2(n+1)(4k+n(n+2))}{(4(n+2)(n^2+2n+2)k-(5n^3+16n^2+18n+8))^3} \\
&\times [(n+1)(7n^2+20n+16)-(48+90n+54n^2+11n^3)k+4(n+2)^3k^2].
\end{aligned} \tag{5}
$$

From the equation, we have the following proposition.

[5] Note that the upper bound of k is different from that in the duopoly case. In this subsection, we use differentiation to derive the upper bound whereas in the previous subsection we use the difference between the duopoly and the monopoly cases. The methodological difference leads to slightly different results.

Proposition 3 *The incumbent's profit is increasing in n if and only if*

$$k < \frac{11n^3 + 54n^2 + 90n + 48}{8(n+2)^3} + \frac{\sqrt{9n^6 + 84n^5 + 384n^4 + 984n^3 + 1380n^2 + 960n + 256}}{8(n+2)^3}. \tag{6}$$

This is summarized in Figure 4. When n is large and k is small, an additional entry can increase the profit of the incumbent. As explained before, when k is small, an increase in the number of entrants accelerates the R&D incentive of the incumbent. An entry can be a credible commitment of the incumbent to invest more. This commitment diminishes the incentives of entrants to invest. As a result, an additional entry can *increase* the incumbent's profit.

[Figure 4 here]

Entry and welfare In this model, we can make examples of both excess and insufficient entry. When k is small, whether or not entry is excessive depends on the fixed entry costs. We can also show that when k is large, excess entry appears.

In Figure 5, we depict three curves. The curve $\pi_E = F$ indicates the equilibrium number of entrants given k. This curve shows that the equilibrium number of entrants increases with the increase in k. The curve $\partial SW^O/\partial n = F$ indicates a necessary condition that social welfare is maximized. The curve $SW^M = SW^O - nF$ indicates that social welfare under the monopoly case is equal to that under the n-firm oligopoly case. The upper (lower) region of $SW^M = SW^O - nF$ indicates that $SW^M > SW^O - nF$ ($SW^M < SW^O - nF$). If $\partial SW^O/\partial n = F$ is on the lower region of $SW^M = SW^O - nF$, the social optimal number of entrants is indicated by the thick curve on $\partial SW^O/\partial n = F$; otherwise, the optimal number is zero (monopoly is the best). For instance, we now suppose that k is smaller than 1.57. The social optimum number of entrants is more than 30 although the equilibrium number of entrants is less than 10. This is an example of insufficient entry. We now suppose that k is larger than 1.6. The social optimum number of entrants is zero although the equilibrium number is larger than five. This is an example of excess entry. This property is summarized in the following proposition.

Proposition 4 *When k is small enough, the equilibrium number of firms is excessive from the viewpoint of social welfare.*

[**Figure 5 here**]

We now discuss the intuition behind the tendency. As in the standard Cournot models, the business-stealing effect leads to excess entry (Mankiw and Whinston, 1986; Suzumura and Kiyono, 1987; and Okuno-Fujiwara and Suzumura, 1993). In our model, additional effects exist. When k is small (the cost-reducing technology of the incumbent is not so inefficient), entry enhances the investment of the incumbent (Proposition 2). This has two effects: one is positive, the other is negative. The positive effect is that the improvement of production efficiency enhances competition. The negative effect is the duplication of the R&D investments undertaken by the firms. When k is large, the negative effect is significant because the incumbent's R&D technology is inefficient. On the other hand, the incumbent's stronger R&D incentive caused by entry diminishes the incentives of potential entrants to enter the market. That is, this strong incentive of the incumbent can deter beneficial entry. When k is small enough, this entry deterrence effect dominates the standard business-stealing effect.

In Figure 6, we change the level of the entry cost F. The left-hand (right-hand) figure shows a case in which F is large (small). As the value of F decreases, the range of k, which leads to insufficient entry, increases.

[**Figure 6 here**]

When F is small, the socially optimal number of entrants is large. As mentioned earlier, a large number of entrants tends to deter beneficial entry because the large number enhances the incumbent's R&D investment. Therefore, when F is small enough, the equilibrium number of entrants tends to be insufficient.

5 Concluding Remarks

This paper has considered a multi-market model wherein an incumbent meets entrants in one market while it is a monopolist in the other market, and investigates how the market entry affects the incumbent's R&D, its profits, and social welfare. We show that entry can enhance the total R&D expenditure of the incumbent. We also show that an additional entry can increase the incumbent's profit when the number of existing entrants is large. Furthermore, our analysis of social welfare shows that depending on the fixed entry costs and R&D technologies, both insufficient and excess entry can appear in equilibrium. These findings not only provide useful implications for firms' strategic behaviors on R&D investments, but also offer meaningful implications for entry regulators with welfare concerns.

Our model is a standard Cournot type with multiple markets, and has been constructed based on some observations in which some leading firms with advanced technologies attempt to provide other new products (i.e., those firms can enter into new markets) by fully exploiting their standard and advanced technologies. Those leading firms also tend to encourage minor firms to enter the market of products with standard technologies. Therefore, the market structure of our model is applicable to various practical situations.

There remain some limitations of the model, which should be addressed in the future. First, the two products discussed here are independent of each other on the demand side. It is natural to consider the consumption relationship between the two products. For example, Dawid et al. (2010) consider that a firm can provide a new product that is horizontally and vertically differentiated from the current product by product innovation projects. The consumption relationships might influence the effects of process R&D competition. This topic can be considered in future research. Second, we can incorporate licensing into our model. For instance, the incumbent firm can allow other firms to enter the monopolized market subject to the acceptance of licensing contracts. In this setting, it is not obvious whether or not the incumbent licenses its technology because new entry caused by the license alter the incentives of the entrants to engage in R&D. This can also be addressed in future research.

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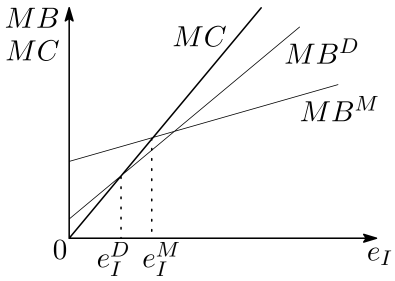

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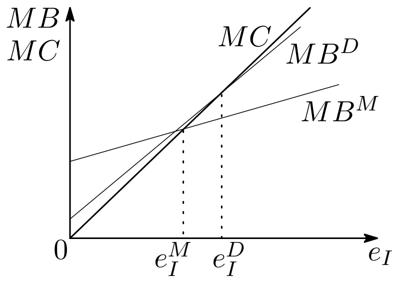

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Figure 1: Marginal benefit and marginal cost of investment

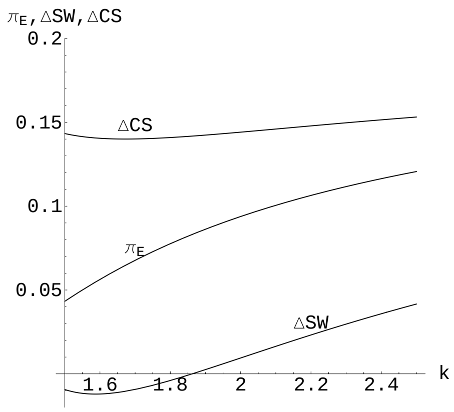


Figure 2: π_E, ΔSW, and ΔCS (the duopoly case)

Note: π_E, ΔSW, and ΔCS are divided by $(1-c)^2$ without loss of generality.

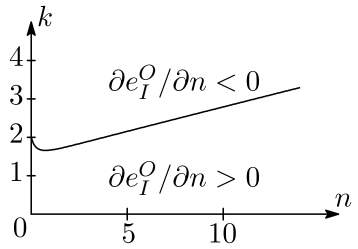


Figure 3: Entries and the incumbent's investment

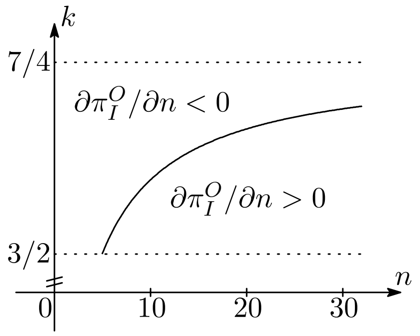
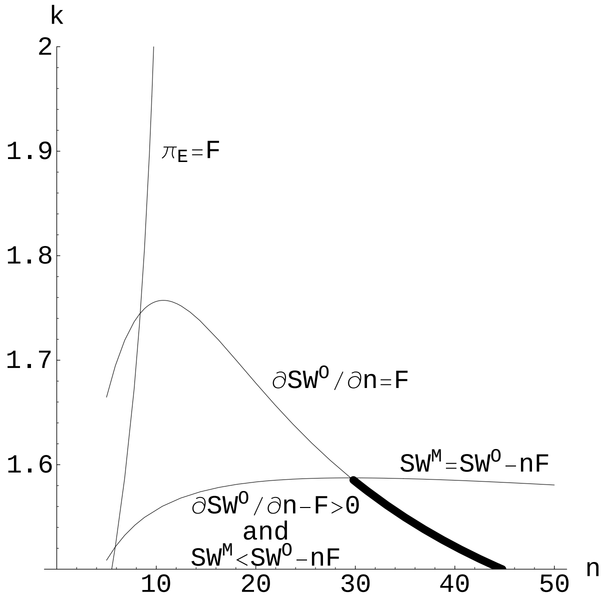
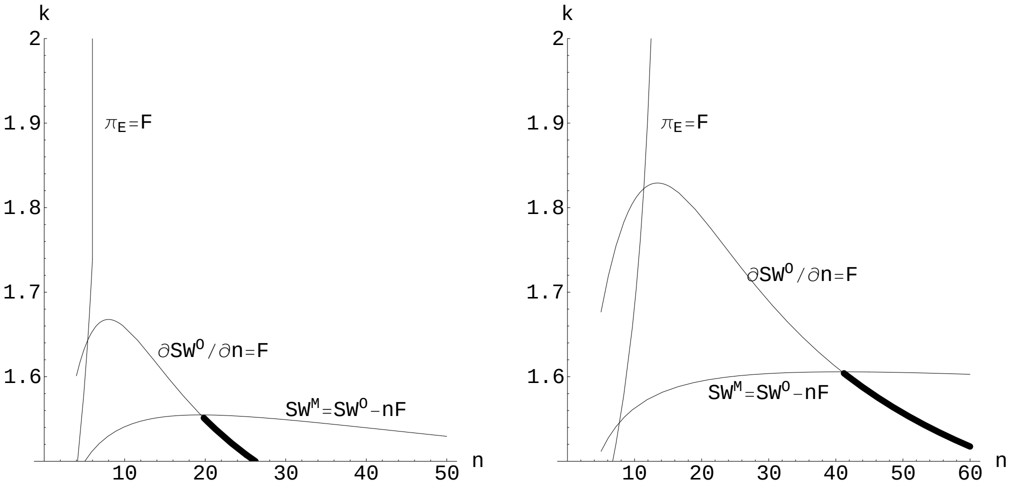


Figure 4: Entries and the incumbent's profit



$\pi_E = F$ **and** $\partial(SW^O - Fn)/\partial n = 0$

Figure 5: Examples of insufficient/excess entries ($F/(1-c)^2 = 1/1250$**)**



$\pi_E = F$ **and** $\partial(SW^O - Fn)/\partial n = 0$ $\quad$ $\pi_E = F$ **and** $\partial(SW^O - Fn)/\partial n = 0$

Figure 6: Examples of insufficient/excess entries

(Left: $F/(1-c)^2 = 1/500$**, Right:** $F/(1-c)^2 = 1/2500$**)**