Horizontal Licensing: A Strategic Tool for Joint Profit Maximization

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April, 2004

Abstract

While previous scholarship has considered horizontal licensing as a strategic tool, this paper addresses its use as a strategic tool in a heretofore unconsidered domain. It is demonstrated that two incumbent firms confronted with the threat of entry by a third firm can utilize a horizontal licensing contract to jointly maximize their profits.

Honors Thesis submitted in partial fulfillment of the requirements for

Graduation with Distinction in Economics in Trinity College of Duke University.

I would like to acknowledge Tracy Lewis, Chris Laincz, Claire Kramer, Paul Dudenhefer, and Stephanie Houghton for their advice and guidance in the process of writing this thesis.

I. Introduction

■ The United States Patent System promotes technological innovation by providing the patentee with a legal right to a monopoly and protecting this right from infringement by competitors. To balance the monopoly rights supplied by the patent system, the Sherman Antitrust Act maintains competition in the marketplace by regulating the monopolistic power of firms. In the event that a monopoly, attained by exclusive rights to patented technology, violates antitrust laws, the legal system determines a just resolution. The resolution of one such antitrust case in the semiconductor industry, the United States of America vs. International Business Machines Corporation (IBM), resulted in the 1956 Antitrust Consent Decree. The Decree required IBM to license its patented technologies to competitors, thus setting a precedent for the resolution of subsequent antitrust disputes in the semiconductor industry: horizontal licensing.

Although the court-imposed sanctions of the 1956 Antitrust Consent Decree expired in 1961, IBM continues to license its patented technologies to competitors. And IBM is not alone. Currently, nearly sixty percent of semiconductor firms voluntarily engage in horizontal licensing, and other industries have adopted it as a standard practice as well (Cohen et al 2000).

In a horizontal licensing contract, a firm relinquishes its intellectual property rights to a competitor and thus establishes an environment in which its rival may introduce duplicate technology into the market. Through this counter-intuitive strategy, a firm forfeits its competitive advantage and seemingly diminishes the rewards from innovation. This yields the intriguing question: What motivates a firm to offer a licensing contract to a competitor?

This paper offers an original answer: It shows that a firm will offer a licensing contract to a competitor to maximize its profits, but only under certain conditions. Those conditions arise when the firm is part of a duopolistic industry producing a homogeneous good, and the firm, and its rival, are confronted with the threat of entry by a third firm. This paper argues that when faced with a potential entrant that has a low fixed cost, the two firms can achieve greater joint profits through a licensing contract than through the acquisition of one firm by the other. However, when faced with a potential entrant that has a high fixed cost, the two firms can maximize their joint profits through an acquisition agreement.

Consider two incumbents, one producing a low-cost technology and the other a high-cost technology, in a duopolistic industry confronted with possible entry by a single firm that has developed an alternative technology to those of the incumbents. The firm must incur an irreversible fixed set-up cost to enter the market. Assume that in the Cournot equilibrium of the ensuing production game that the potential entrant would earn a strictly positive profit if the two incumbents were to independently produce with their respective technologies. In this scenario, two strategies are available to the incumbents as strategic tools to maximize their joint profits: (1) the incumbents can merge to form one firm that produces utilizing the low-cost technology, or (2) the low-cost incumbent can license its technology to the high-cost incumbent, whereupon the firms produce independently.

In the event that the firms merge, the quality of the competition in the industry renders entry unprofitable for a potential entrant with high fixed costs. Thus, the two incumbents attain a monopoly position in the industry and achieve maximum joint profits. For an entrant with a low fixed cost, however, entry will occur and monopoly pricing through acquisition is not possible. In this case, the two incumbents can achieve greater joint profits through a licensing contract than through a merger.

In a licensing contract, the low-cost incumbent can (but will not necessarily) charge the high-cost incumbent a per-unit royalty to produce the low-cost technology. This royalty determines how competitive the industry is, which in turn determines the profitability of entry. This paper demonstrates that licensing can deter a firm from entering that would otherwise join the market if the two incumbents were to merge. Thus licensing may be a profit-maximizing choice when entry costs are sufficiently low.

The conditions under which the two strategies are attained as equilibria are investigated in the next section of this paper.

Although this paper proposes an original model for horizontal licensing, the idea that horizontal licensing can serve a strategic purpose is not a new one. Gallini (1984) demonstrates that when an incumbent firm is confronted with the entrance of a rival firm *ex ante* to research and development, the incumbent firm will elect to license its patented technology to the entrant to dissuade its new rival from pursuing further research and development. She illustrates that through horizontal licensing, the incumbent firm can both secure its market share and protect itself from the possible introduction of a superior technology rival to its own. Shapiro (1985) confirms Gallini's findings, but in the context of a duopolistic industry, and then shifts his analysis to the case of horizontal licensing *ex post* to research and development. In this case, he argues a firm will license its patented technology to its competitor in order to manipulate the behavior of that firm by controlling the competitor's marginal cost of production through a licensing royalty rate. Rockett (1990) considers a scenario similar to Gallini's in which an incumbent with an expiring patent is faced with sequential entry by two firms. She demonstrates that the incumbent can block the entry of the stronger entrant by licensing its patented technology to the weaker firm before the patent expires and thus protect its market share in the subsequent period.

These papers provide insight on the incentive a firm has to horizontally license to a competitor in a unique domain. Gallini investigates licensing to an entrant *ex ante* to research and development, Shapiro analyzes *ex post* licensing in a duopoly, and Rockett addresses licensing when a patent is expiring. This paper focuses on the strategic use of horizontal licensing in a heretofore unconsidered domain. What is investigated here is the incentive two incumbent firms might have to enter into a horizontal licensing agreement when confronted with the threat of entry by a third firm.

The next section of this paper presents a formal model.

II. The Model

■ This section presents a formal model that captures the incentives for two incumbents to enter into a horizontal licensing agreement when confronted with the possibility of entry by a third firm. Consider an industry, initially composed of two firms, 1 and 2, producing a homogeneous good. Given the firms' technologies, production costs are c_1 and c_2 respectively for firms 1 and 2. The inverse demand curve for the industry is assumed to be linear with

$$P(Q) = \alpha - \beta Q, \tag{1}$$

where $\alpha > c_1$ so that the good will be produced, $\beta > 0$, Q denotes the industry output, and P the demand price.

Suppose $c_1 << c_2$, then given the ability to produce both technologies, it is individually rational for both firms to specialize in the production of the low-cost technology. This preference for producing the low-cost technology establishes the following: (1) if the firms merge, in the resulting super-firm only the low-cost technology is employed, and (2) if one firm licenses to the other, only the low-cost technology is employed.

Firms 1 and 2 will be referred to hereafter as the respective low-cost and high-cost incumbents. It is assumed that the two firms have incurred the sunk costs F_1 and F_2 in order to produce their respective technologies. In the proposed model, the two incumbent firms seek to maximize their joint profits when confronted with possible entry by a third firm (firm 3) which can produce at constant marginal cost, c_3, once it incurs the fixed cost, F_3.[1]

The sequential game at the production stage proceeds as follows. The industry is confronted with the threat of entry by firm 3. Two strategies are available to the incumbents as strategic tools to maximize their joint profits: (1) the incumbents can merge for a lump-sum fee B, or (2) the low-cost incumbent can license its technology to the high-cost incumbent. If the two incumbents decide to enter a licensing contract, the contract is binding and will consist of two parts, a fixed fee R and a per-unit royalty r. Once the two incumbents reach a decision, the potential entrant then decides whether or not to enter the industry. The production game to follow is Cournot. The technologies of the incumbents and potential entrant as well as the terms of any contract are all common knowledge.

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[1] The fixed cost of the potential entrant, F_3, is assumed to be less than $F_3^b \equiv (\alpha - 3c_1 + c_2 + c_3)^2/16\beta$ such that the threat of entry is credible. See Appendix A.

It is clear from the above discussion that there are four outcomes of interest:[2]

1. Acquisition-Entry

   The incumbents merge and firm 3 enters.

2. Acquisition-Deterrence

   The low-cost incumbent acquires the high-cost incumbent and entry of firm 3 is deterred.

3. Licensing-Entry

   The low-cost incumbent licenses its technology to the high-cost incumbent and firm 3 enters.

4. Licensing-Deterrence

   The low-cost incumbent licenses its technology to the high-cost incumbent and entry of firm 3 is deterred.

Consider first the Acquisition-Entry outcome in which the two incumbents form a super-firm (denoted 1^*) through the low-cost incumbent acquiring the high-cost incumbent for a lump-sum fee B[3]. If the potential entrant (firm 3) enters the industry, it is the only rival of the super-firm.

1. The Acquisition-Entry Outcome

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[2] It should be noted that there is a fifth possible outcome that will not be considered in this analysis. The two incumbents also have the option to remain independent; however, this outcome is not rational if the two incumbents seek to maximize their joint profits because it is always more efficient to produce at a lower marginal cost.

[3] The value of *B* will not be explicitly considered in this analysis since it is assumed that the two firms will jointly maximize their profits.

In the Acquisition-Entry outcome, the potential entrant decides to enter and firms 1^* and 3 face the optimization problems under Cournot conjectures given by

$$\max_{q1*} [P(q_{1*} + q_3) - c_1]q_{1*} - F_1 - F_2$$

(2a)

$$\max_{q3} [P(q_{1*} + q_3) - c_3]q_3 - F_3$$

(2b)

Let Π_i^{AE}, $i = 1^*,3$, denote the profit of firm i in the Acquisition-Entry outcome. It is verified in Appendix B that the profits of firms 1^* and 3 are given by

$$\Pi_{1*}^{AE} = (\alpha - 2c_1 + c_3)^2/9\beta - F_1 - F_2$$

(3a)

$$\Pi_3^{AE} = (\alpha - 2c_3 + c_1)^2/9\beta - F_3$$

(3b)

From (3b) it follows that when the fixed cost of the potential entrant is greater than or equal to the critical lower-bound F_3^{Ac} given by

$$F_3^{Ac} \equiv (\alpha - 2c_3 + c_1)^2/9\beta$$

(4)

entry is rendered unprofitable for firm 3. Thus, when the fixed cost of the potential entrant lies in the range $F_3^{Ac} \leq F_3$, there cannot be an Acquisition-Entry outcome because the acquisition itself automatically deters the entry of firm 3. In other words, when its fixed cost falls in this range, the potential entrant is not viable in the Acquisition-Entry outcome discussed above. This result is recorded in the following lemma.

Lemma 1: *When the fixed cost of the potential entrant lies in the range* $F_3^{Ac} \leq F_3$, *the acquisition of the high-cost incumbent by the low-cost incumbent deters the entry of the potential entrant.*

2. The Acquisition-Deterrence Outcome

In the Acquisition-Deterrence outcome, since the acquisition deters the entry of firm 3, the super-firm monopolizes the industry and confronts the optimization problem

$$\max_{q1*} [P(q_{1*}) - c_1]q_{1*} - F_1 - F_2$$

(5)

Let Π_{1*}^{AD} denote the equilibrium profit of firm 1^* in the Acquisition-Deterrence outcome. It is verified in Appendix C that this profit is given by

$$\Pi_{1*}^{AD} = (\alpha - c_1)^2/4\beta - F_1 - F_2$$

(6)

Now consider the scenario in which the low-cost incumbent (firm 1) licenses its technology to the high-cost incumbent (firm 2) for a fixed fee *R* and a per-unit royalty *r* such that the marginal cost of production for firm 2 will be $c_1 + r$ for producing the low-cost technology. If the potential entrant (firm 3) enters the industry, the industry will consist of three competitors.

3. The Licensing-Entry Outcome

In the Licensing-Entry outcome, the potential entrant decides to enter and firms 1, 2, and 3 face the optimization problems under Cournot conjectures given by

$$\max_{q1} [P(q_1 + q_2 + q_3) - c_1]q_1 + rq_2 + R - F_1$$

(7a)

$$\max_{q2} [P(q_1 + q_2 + q_3) - c_1 - r]q_2 - R - F_2$$

(7b)

$$\max_{q3} [P(q_1 + q_2 + q_3) - c_3]q_3 - F_3$$

(7c)

where the second and third terms in (7a) represent the royalty and fixed fee payments received by the low-cost incumbent from the high-cost incumbent for producing its low-cost technology. Let Π_i^{LE}, i=1,2,3, denote the equilibrium profit of firm *i* in the

Licensing-Entry outcome. It is verified in Appendix D that the profits of firms 1, 2, and 3 are given by

$$\Pi_1^{LE} = (\alpha - 2c_1 + c_3 + r)^2/16\beta + r(\alpha - 2c_1 - 3r + c_3)/4\beta + R - F_1$$

(8a)

$$\Pi_2^{LE} = (\alpha - 2c_1 - 3r + c_3)^2/16\beta - R - F_2$$

(8b)

$$\Pi_3^{LE} = (\alpha - 3c_3 + 2c_1 + r)^2/16\beta - F_3$$

(8c)

It follows that the joint profit of firms 1 and 2 is given by

$$\Pi_J^{LE} = [(\alpha - 2c_1 + c_3 + r)^2 + (\alpha - 2c_1 - 3r + c_3)^2]/16\beta + r(\alpha - 2c_1 - 3r + c_3)/4\beta - F_1 - F_2 \qquad (9)$$

In the Licensing-Entry outcome, the two incumbents will maximize their joint profits with respect to r. Maximizing (9) with respect to the per-unit royalty rate r yields the optimal marginal cost c_4^* of a license

$$c_4^* = c_1$$

(10)

This implies that the optimal per-unit royalty rate r=0. Thus, the optimal licensing contract consists solely of a fixed fee R. This result is recorded in the following lemma.

Lemma 2: *The optimal licensing contract consists solely of a fixed fee R*[4].

Intuition for this result may be had as follows. A reduction in the per-unit royalty *r* increases the competition facing the potential entrant in the industry and transfers a proportion of the potential entrant's profits to the two incumbents. By agreeing to a licensing contract consisting only of a fixed fee *R* (i.e., r=0), the two incumbents maximize the competition in the industry and thus jointly maximize their joint profits.

When the optimal licensing contract is negotiated, the Licensing-Entry outcome equilibrium profits for firms 1, 2, and 3 are given by

$$\Pi_1^{LE*} = (\alpha - 2c_1 + c_3)^2/16\beta + R - F_1$$

(11a)

$$\Pi_2^{LE*} = (\alpha - 2c_1 + c_3)^2 /16\beta - R - F_2$$

(11b)

$$\Pi_3^{LE*} = (\alpha - 3c_3 + 2c_1)^2 /16\beta - F_3$$

(11c)

4 For the remainder of the analysis, it is assumed that an optimal licensing contract is negotiated.

It follows that the optimal joint profit of firms 1 and 2 is given by

$$\Pi_J^{LE*} = (\alpha - 2c_1 + c_3)^2/8\beta - F_1 - F_2$$

(12)

From (11c) it follows that when the fixed cost of the potential entrant is greater than or equal to the critical lower-bound F_3^{Lc} given by

$$F_3^{Lc} \equiv (\alpha - 3c_3 + 2c_1)^2/16\beta$$

(13)

entry is rendered unprofitable for firm 3. Thus, when the fixed cost of the potential entrant lies in the range

$F_3^{Lc} \leq F_3$, there cannot be a Licensing-Entry outcome because the licensing of the low-cost technology itself automatically deters the entry of firm 3. In other words, when its fixed cost falls in this range, the potential entrant is not viable in the Licensing-Entry outcome discussed above. This result is recorded in the following lemma.

Lemma 3: *When the fixed cost of the potential entrant lies in the range $F_3^{Lc} \leq F_3$, the low-cost incumbent licensing its technology to the high-cost incumbent deters the entry of the potential entrant.*

4. The Licensing-Deterrence Outcome

In the Licensing-Deterrence outcome, licensing deters the entry of firm 3 and the two incumbents solve the optimization problems under Cournot conjectures given by

$$\max_{q1} [P(q_1 + q_2) - c_1]q_1 + R - F_1$$

(14a)

$$\max_{q2} [P(q_1 + q_2) - c_1]q_2 - R - F_2$$

(14b)

Let Π_i^{LD}, i = 1,2, denote the equilibrium profit of firm i in the Licensing-Deterrence outcome. It is verified in Appendix E that the profits of firms 1 and 2 are given by

$$\Pi_1^{LD} = (\alpha - c_1)^2/9\beta + R - F_1$$

(15a)

$$\Pi_2^{LD} = (\alpha - c_1)^2/9\beta - R - F_2$$

(15b)

It follows that the joint profit of firms 1 and 2 is given by

$$\Pi_J^{LD} = 2(\alpha - c_1)^2/9\beta - F_1 - F_2$$

(16)

III. The Results

▪ The previous section formally set out the logical options open to the incumbents confronted with the possibility of entry. This paper will now determine the conditions under which the two incumbents will enter a horizontal licensing agreement to jointly maximize their profits.

Consider first the scenario in which both a licensing contract and an acquisition agreement deter entry of the third firm such that the only viable outcomes are Licensing-Deterrence and Acquisition-Deterrence. On comparing the incumbents' joint profit Π_J^{LD} in the Licensing-Deterrence outcome, given in (16), with their joint profit $\Pi_{I^*}^{AD}$ in the Acquisition-Deterrence outcome, given in (6), it follows that the two incumbents will prefer the Acquisition-Deterrence outcome to the Licensing-Deterrence outcome. It is also shown that the two incumbents will prefer the Acquisition-Deterrence outcome even if licensing does not deter entry by the third firm. This can be seen by comparing the incumbents' joint profit in the Acquisition-Deterrence outcome with their joint profit Π_J^{LE*} in the Licensing-Entry outcome, given in (12).

Thus, from the above argument , the two incumbents will prefer an acquisition agreement, when it deters the entry of the third firm, to a licensing contract . From

Lemma 1, this will occur if and only if $F_3 \geq F_3^{Ac}$. This result is recorded in the following proposition.

Proposition 1: *When the fixed cost of the potential entrant is greater than or equal to the critical value* F_3^{Ac}*, the two incumbents will utilize an acquisition agreement to maximize their joint profit.*

As noted earlier, an acquisition agreement increases the quality of the competition in the industry[5] and, for potential entrants with high fixed costs, renders entry unprofitable. Thus, through one incumbent acquiring the other, the two firms can attain a monopoly in the industry when the potential entrant is deterred and achieve the maximum joint profit possible.

Now consider the scenario in which the third firm always enters the industry such that the only viable outcomes are Licensing-Entry and Acquisition-Entry. On comparing the incumbents' joint profit in the Licensing-Entry outcome with their joint profit $\Pi_{1^*}^{AE}$ in the Acquisition-Entry outcome, given in (3a), it follows that the two incumbents will prefer the Licensing-Entry outcome to the Acquisition-Entry outcome.

[5] Even though the number of competitors is reduced through an acquisition, the resulting super-firm produces only the low-cost technology and is thus more competitive.

Now suppose that licensing deters entry of the third firm into the industry. It follows that the two incumbents will still prefer a licensing contract. This can be seen by comparing the incumbents' joint profit in the Licensing-Deterrence outcome with their joint profit in the Acquisition-Entry outcome.

Thus, from the above argument, the two incumbents will prefer a licensing contract to an acquisition agreement when the acquisition agreement does not deter the entry of the third firm into the industry. From Lemma 1, this will occur if and only if $F_3 < F_3^{Ac}$. This result is recorded in the following proposition.

Proposition 2: *When the fixed cost of the potential entrant is less than the critical value* F_3^{Ac}*, the two incumbents will utilize a licensing contract to maximize their joint profit.*

By agreeing to an acquisition, the incumbents increase the quality of the competition in the industry while reducing the number of competitors, but by engaging in an optimal licensing contract, the incumbents increase the quality of the competition without reducing the number of competitors in the industry. Thus, when an acquisition agreement fails to deter the entry of the third firm, the two incumbents are jointly more profitable through a licensing contract than through an acquisition agreement.

IV. Conclusions

■ This paper set out to determine the conditions under which licensing will occur between competitors and has demonstrated that two incumbent firms will enter a horizontal licensing agreement to jointly maximize their profits when confronted with the threat of entry by a third firm with a fixed cost $F_3 < F_3^{Ac}$. In the process of determining when licensing will occur between competitors, this paper has also illustrated that when $F_3 \geq F_3^{Ac}$, the two incumbents will maximize their joint profit through an acquisition agreement.

There is another interesting finding that has not yet been discussed in this paper: the profits that the two incumbents can attain through a licensing contract can be almost as high as those in a monopoly. Observe first that the optimal outcome would be the one in which the low-cost incumbent acquires the high-cost incumbent and in the process deters entry of the third firm. But when this optimal outcome is not possible (i.e., an acquisition agreement will not deter the entry of the third firm), the two incumbents can still deter the entry of the third firm through a licensing contract when the entrant's fixed cost $F_3 \geq F_3^{Lc}$. By doing so, the two incumbents can attain joint profits almost as high as they would in the optimal outcome. This result implies that when monopoly profits are unattainable through an acquisition agreement, the two incumbents can attain near monopoly-level profits through the low-cost incumbent licensing its technology to the high-cost incumbent for a fixed fee R. Note that the optimal value of the licensing fixed fee R has not been considered in this analysis. An interesting direction for future work or research would be to determine the optimal value of the licensing fixed fee R and investigate the division of the joint profits between the two incumbents.

References

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Appendix A

▪ ***Derivation of the upper-bound F_3^b such that firm 3's threat of entry is credible.***

Consider an industry that consists of three firms: the low and high-cost incumbents (firms 1 and 2 respectively) and the entrant (firm 3). If q_i denotes the output of firm i, the optimization problems confronting firms 1, 2, and 3 under Cournot conjectures are given by

$$\max_{q1} [P(q_1 + q_2 + q_3) - c_1]q_1 - F_1$$

(A1)

$$\max_{q2} [P(q_1 + q_2 + q_3) - c_2]q_2 - F_2$$

(A2)

$$\max_{q3} [P(q_1 + q_2 + q_3) - c_3]q_3 - F_3$$

(A3)

The respective first-order conditions for profit-maximization are given by

$$P(q_1 + q_2 + q_3) - c_1 + q_1 P'(q_1 + q_2 + q_3) = 0$$

(A4)

$$P(q_1 + q_2 + q_3) - c_2 + q_2 P'(q_1 + q_2 + q_3) = 0$$

(A5)

$$P(q_1 + q_2 + q_3) - c_3 + q_3 P'(q_1 + q_2 + q_3) = 0$$

(A6)

and yield the firms' best-response functions given by

$$R_1 = (\alpha - \beta(q_2 + q_3) - c_1)/2\beta$$

(A7)

$$R_2 = (\alpha - \beta(q_1 + q_3) - c_2)/2\beta$$

(A8)

$$R_3 = (\alpha - \beta(q_1 + q_2) - c_3)/2\beta$$

(A9)

Solving the best-response functions given in (A7), (A8), and (A9) yields the optimal outputs for firms 1, 2, and 3 given by

$$q_1 = (\alpha - 3c_1 + c_2 + c_3)/4\beta$$

(A10)

$$q_2 = (\alpha - 3c_2 + c_1 + c_3)/4\beta$$

(A11)

$$q_3 = (\alpha - 3c_3 + c_1 + c_2)/4\beta$$

(A12)

Substituting the optimal outputs given in (A10), (A11), and (A12) for q_1, q_2, and q_3 in (A1), (A2), and (A3) yields the equilibrium profits for firms 1, 2, and 3 given by

$$\Pi_1^I = (\alpha - 3c_1 + c_2 + c_3)^2/16\beta - F_1$$

(A13)

$$\Pi_2^I = (\alpha - 3c_2 + c_1 + c_3)^2/16\beta - F_2$$

(A14)

$$\Pi_3^I = (\alpha - 3c_3 + c_1 + c_2)^2/16\beta - F_3$$

(A15)

From (A15) it follows that entry of firm 3 is profitable only when its fixed cost F_3 is less than the upper-bound F_3^b given by

$$F_3^b \equiv (\alpha - 3c_3 + c_1 + c_2)^2/16\beta$$

(A16)

Appendix B

▪ ***Derivation of the equilibrium profits of the super-firm and entrant in the Acquisition-Entry Outcome.***

The industry consists of only two firms, the super-firm (firm 1^*) and the entrant (firm 3), as the low-cost incumbent has acquired the high-cost incumbent (firm 2) for the lump-sum fee B. If q_i denotes the output of firm i, the optimization problems facing firms 1^* and 3 under Cournot conjectures are given by

$$\max_{q1*} [P(q_{1*} + q_3) - c_1]q_{1*} - F_1 - F_2$$

(B1) $$\max_{q2} [P(q_{1*} + q_3) - c_3]q_3 - F_3$$

(B2)

The respective first-order conditions for profit-maximization are given by

$$P(q_{1*}+ q_3) - c_1 + q_{1*} P'(q_{1*} + q_3) \quad = 0$$

(B3) $$P(q_{1*} + q_3) - c_3 + q_3 P'(q_{1*} + q_3) \quad = 0$$

(B4)

and yield the firms' best-response functions given by

$$R_{1*} = (\alpha - \beta q_3 - c_1)/2\beta$$

(B5)

$$R_3 = (\alpha - \beta q_{1*} - c_3)/2\beta$$

(B6)

Solving the best-response functions given in (B5) and (B6) yields the optimal outputs for firms 1^* and 3 given by

$$q_{1^*} = (\alpha - 2c_1 + c_3)/3\beta$$

(B7)

$$q_3 = (\alpha - 2c_3 + c_1)/3\beta$$

(B8)

Substituting the optimal outputs in (B7) and (B8) for q_{1^*} and q_3 in (B1) and (B2) yields the equilibrium profits for firms 1^* and 3 given by

$$\Pi_{1^*}^{AE} = (\alpha - 2c_1 + c_3)^2/9\beta - F_1 - F_2$$

(B9)

$$\Pi_3^{AE} = (\alpha - 2c_3 + c_1)^2/9\beta - F_3$$

(B10)

Appendix C

▪ ***The derivation of the equilibrium profit of the super-firm in the Acquisition-Deterrence Outcome.***

The low-cost incumbent (firm 1) has acquired the high-cost incumbent (firm 2) for a lump-sum fee *B* and monopolizes the industry. The super-firm (firm 1^*) confronts the optimization problem given by

$$\max_{q1^*} [P(q_{1^*}) - c_1]q_{1^*} - F_1 - F_2$$

(C1)

The first-order condition for profit-maximization is given by

$$P(q_{1^*}) - c_1 + q_{1^*} P'(q_{1^*}) = 0$$

(C2)

and yields the optimal output given by

$$q_{1^*} = (\alpha - c_1)/2\beta$$

(C3)

Substituting the optimal output given in (C3) for q_{1^*} given in (C1) yields the equilibrium profit for firm 1^* given by

$$\Pi_{1^*}^{AD} = (\alpha - c_1)^2/4\beta - F_1 - F_2$$

(C4)

Appendix D

Appendix D

▪ ***Derivation of the equilibrium profits of the low-cost and high-cost incumbents and the entrant in the Licensing-Entry Outcome.***

The industry consists of three firms: the low and high-cost incumbents (firms 1 and 2 respectively) and the entrant (firm 3). Firm 1 has licensed its low-cost technology to firm 2 for a fixed fee R and a per unit royalty r, such that the new marginal cost of production for firm 2 is $c_1 + r$ for producing the low-cost technology. The optimization problem confronting firm 1 under Cournot conjectures is given by

$$\max_{q1} [P(q_1 + q_2 + q_3) - c_1]q_1 + rq_2 + R - F_1 \quad \text{(D1)}$$

where the second and third terms in the above objective function represent the royalty and fixed fee payments received by firm 1 from firm 2. Firms 2 and 3 confront the optimization problems given by

$$\max_{q2} [P(q_1 + q_2 + q_3) - c_1 - r]q_2 - R - F_2 \quad \text{(D2)}$$

$$\max_{q3} [P(q_1 + q_2 + q_3) - c_3]q_3 - F_3 \quad \text{(D3)}$$

The respective first-order conditions for profit-maximization are given by

$$P(q_1 + q_2 + q_3) - c_1 + q_1 P'(q_1 + q_2 + q_3) = 0$$

(D4)

$$P(q_1 + q_2 + q_3) - c_1 - r + q_2 P'(q_1 + q_2 + q_3) = 0$$

(D5)

$$P(q_1 + q_2 + q_3) - c_3 + q_3 P'(q_1 + q_2 + q_3) = 0$$

(D6)

and yield the firms' best-response functions given by

$$R_1 = (\alpha - \beta(q_2 + q_3) - c_1)/2\beta$$

(D7)

$$R_2 = (\alpha - \beta(q_1 + q_3) - c_1 - r)/2\beta$$

(D8)

$$R_3 = (\alpha - \beta(q_1 + q_2) - c_3)/2\beta$$

(D9)

Solving the best-response functions given in (D7), (D8), and (D9) yields the optimal outputs for firms 1, 2, and 3 given by

$$q_1 = (\alpha - 2c_1 + r + c_3)/4\beta$$

(D10)

$q_2 = (\alpha - 2c_1 - 3r + c_3)/4\beta$

(D11)

$q_3 = (\alpha - 3c_3 + 2c_1 + r)/4\beta$

(D12)

Substituting the optimal outputs given in (D10), (D11), and (D12) for q_1, q_2, and q_3 in (D1), (D2), and (D3) yields the equilibrium profits for firms 1, 2, and 3 given by

$\Pi_1^{LE} = (\alpha - 2c_1 + r + c_4)^2/16\beta + \mathrm{r}(\alpha - 2c_1 - 3r + c_3)/4\beta + R - F_1$

(D13)

$\Pi_2^{LE} = (\alpha - 2c_1 - 3r + c_3)^2/16\beta - R - F_2$

(D14)

$\Pi_3^{LE} = (\alpha - 3c_3 + 2c_1 + r)^2/16\beta - F_3$

(D15)

Appendix E

▪ ***Derivation of the equilibrium profits of the low-cost and high-cost incumbents in the Licensing-Deterrence Outcome.***

The industry consists of only two firms, the low-cost incumbent (firm 1) and the high-cost incumbent (firm 2), as licensing has deterred entry by firm 3 into the industry. Both incumbents use the low-cost technology as firm 1 has licensed its low-cost technology to firm 2 for a fixed fee R. The optimization problem confronting firm 1 under Cournot conjectures is given by

$$\max_{q1}\ [P(q_1 + q_2) - c_1]q_1 + R - F_1$$

(E1)

where the second term in the above objective function represents the fixed fee payment received by firm 1 from firm 2. Firm 2 confronts the optimization problem given by

$$\max_{q2}\ [P(q_1 + q_2) - c_1]q_2 - R - F_2$$

(E2)

The respective first-order conditions for profit-maximization are given by

$$P(q_1 + q_2) - c_1 + q_1\, P'(q_1 + q_2) = 0$$

(E3)

$$P(q_1 + q_2) - c_1 + q_2\, P'(q_1 + q_2) = 0$$

(E4)

and yield the firms' best-response functions given by

$$R_1 = (\alpha - \beta q_2 - c_1)/2\beta$$

(E5)

$$R_2 = (\alpha - \beta q_1 - c_1)/2\beta$$

(E6)

Solving the best-response functions given in (E5) and (E6) yields the optimal outputs for firms 1 and 2 given by

$q_1 = (\alpha - c_1)/3\beta$

(E7)

$q_2 = (\alpha - c_1)/3\beta$

(E8)

Substituting the optimal outputs given in (E7) and (E8) for q_1 and q_2 in (E1) (E2) yields the equilibrium profits for firms 1 and 2 given by

$\Pi_1^{LD} = (\alpha - c_1)^2/9\beta + R - F_1$

(E9)

$\Pi_2^{LD} = (\alpha - c_1)^2/9\beta - R - F_2$