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When is entry deterrence the wiser strategy for a firm?

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Abstract

This paper examines the idea that if an incumbent firm deviates from short-term profit maximization behavior and deters the entry of a potential entrant at the expense of higher profit, then its own mid-/long-term profit maximization is achieved. The paper confirms the importance of the entry-deterrence behavior of the incumbent firm by using numerical examples of learning by doing.

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1. Introduction

As the familiar adage goes, "practice makes perfect". Indeed, through on-the-job experience one gains proficiency. More time on the job is associated with lower production costs. We examine learning by doing, a strategic behavior targeted at exploiting experience-related cost advantages.

There are many pioneering works on learning by doing. The empirical and descriptive literature on this topic starts with the work of Wright [1936]. He demonstrates that the direct labor cost of producing an airframe declines with the accumulated number of airframes produced. Rapping [1965] and Sheshinski [1967] find that cumulated industry output yields stronger results than calendar time. Lieberman [1984] examines some empirical results on learning curves based on comprehensive data for 37 chemical products. For each of the 37 products, the raw data on output and capacity are used to compute alternative learning indexes, namely, time, cumulated industry output, cumulated industry capacity, annual rate of industry output, average scale of plant, and rate of new plant investment. The results show that calculated industry output yields the strongest learning curve. Bahk and Gort [1993] examine learning by doing by using time-series and cross-section data for various samples of up to 2,150 plants over a 14-year period; their findings show that new entrants incur costs that incumbent organizations no longer face. Using panel data from 13 member-countries of the Organisation for Economic Cooperation

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and Development (OECD) from 1960 to 1990, Bräuninger and Pannenberg [2002] determine that the long-run level of productivity is reduced if higher unemployment leads to less formal education or to less learning by doing, and find evidence that an increase in unemployment scales down the long-run level of productivity.

An impetus for theoretical investigation on learning by doing arises from Arrow [1962]. He shows that economic agents' technical change is developed out of experience gained within the production process. Spence [1981] analyzes competitive interaction in a market in which unit costs decline with accumulated output and shows that when additions to output lower future costs, it is appropriate for the firm to go beyond the short-run, profit-maximizing level of output. Fudenberg and Tirole [1983] examine learning by doing without strategic interactions in a general continuous-time model and show that output increases over time. Wright [1995] considers the incentive effects of permanent compared to temporary infant industry assistance by using a two-period model with learning by doing and shows that temporary assistance is optimal. Sengupta [2000] extends linear programming models by introducing quality-based learning by doing and evaluates the dynamic implication of a quality-based cost efficiency frontier, where it is assumed that quality-based cumulative experience affects quality control costs.

We consider learning by doing in connection with entry deterrence.[1] As will be evident in the numerical example we shall present on learning by doing, if the incumbent firm deviates from short-term profit maximization behavior and deters entry by the potential entrant at the expense of higher profit, then its own mid-/long-term profit maximization is achieved.

The purpose of this paper is to show the importance of the entry-deterrence behavior of the incumbent firm by using numerical examples on learning by doing. This paper is organized as follows: In section two, we examine the importance of entry-deterrence behavior by using a simple linear numerical example. Section three examines the importance of entry deterrence behavior by using a non-linear numerical example. Finally, section four concludes the paper.

2. Linear numerical example

In this section, we examine the utility of entry deterrence by using a simple numerical example. Let us say that firm 1 develops a product and begins its production. Firm 2, taking notice of the product, then attempts to enter the market.

In period 1, firm 1 enjoys a pure monopoly. After that, firm 2 attempts to enter the market. Firm 2 enters the market if, and only if, its post-entry profit is positive. If firm 2 enters the market, then in each post-entry period, first of all, firm 1 chooses its own output, x_1, and after observing x_1, firm 2 chooses x_2. On the other hand, if firm 2 does not enter the market, then firm 1 prevails as a monopoly.

[1] A great amount of work on entry deterrence has been published. See, for instance, Tirole [1988]; Gilbert [1989]; Ware [1992]; Wilson [1992]; Basu [1993]; and Martin [2001] for excellent surveys.

We consider an industry producing a homogeneous product with the following linear inverse demand function:

$$P = a - b(x_1 + x_2), \quad (1)$$

where $a, b > 0$, $a/b \geq (x_1 + x_2)$, and P is price per unit. Firm 1's profit is

$$\pi_1 = \{a - b(x_1 + x_2)\}x_1 - c_1 x_1, \quad (2)$$

where c_1 is firm 1's marginal cost.

On the other hand, firm 2's profit is

$$\pi_2 = \begin{cases} \{a - b(x_1 + x_2)\}x_2 - (c_2 x_2 + f_2) & \text{Enter} \\ 0 & \text{Stay Out,} \end{cases} \quad (3)$$

where c_2 is firm 2's marginal cost, and f_2 firm 2's fixed set-up cost.

If firm 2 enters the market, then in each post-entry period, firm 1 acts as the Stackelberg leader due to the development of the product, while firm 2 acts as the Stackelberg follower.

In the numerical example, we assume the following: In period 1, $a = 100$, $b = 10$, $c_1 = 50$, and $f_2 = 0$.[2] If firm 2 enters the market, then $c_2 = 50$ in the entry period. In addition, if firm i (i=1,2) continues to produce, as the period advances, its marginal cost decreases by 5 every period due to learning by doing, namely, 50, 45, 40, 35, and so on.

We consider the following four cases:

Case (1): Firm 2 attempts to enter the market in period 2;

Case (2): Firm 2 attempts to enter the market in period 3;

Case (3): Firm 2 attempts to enter the market in period 2 and the amount of demand in the market increases as the period advances, namely, a increases by 10 every period; and

Case (4): Firm 2 attempts to enter the market in period 2 and the amount of demand in the market decreases as the period advances, namely, a decreases by 10 every period.

We examine changes in firm 1's profits both when firm 1 adopts the entry-deterrence behavior and when firm 1 chooses to allow entry in all four cases.

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[2]For firm 1 to deter entry by firm 2, firm 1 must produce more for $f_2 = 0$ than for $f_2 > 0$.

Case (1)

Both firms' profits for this case are given in Table 1. In period 1, firm 1 enjoys a pure monopoly, and hence, firm 1's output and its profit are 2.5 and 62.5, respectively.

In period 2, firm 2 attempts to enter the market. If firm 1 deters entry by firm 2, then $x_1^D = 5$, $c_1 = 45$, and $\pi_1^D = 25$. On the other hand, if firm 1 allows entry by firm 2, then $x_1^S = 3$, $x_2^S = 1$, $\pi_1^S = 45$, and $\pi_2^S = 10$. If only period 2 is considered, since $\pi_1^D = 25 < \pi_1^S = 45$, firm 1 will allow entry by firm 2.

In period 3, $\pi_1^D = 50 < \pi_1^S = 52.813$. Though the profit difference between π_1^D and π_1^S of period 2 is 20, the profit difference between π_1^D and π_1^S of period 3 drops considerably to 2.813.

Table 1. Case 1: Firm 2 attempts to enter the market in period 2

	Period 1	*Period 2*	*Period 3*	*Period 4*	*Period 5*
c_1	50.000	45.000	40.000	35.000	30.000
c_2	-----	-----	-----	-----	-----
x_1^D	2.500	5.000	5.000	5.000	5.000
x_2^D	-----	-----	-----	-----	-----
π_1^D	62.500	25.000	50.000	75.000	100.000
π_2^D	-----	-----	-----	-----	-----
c_1	50.000	45.000	40.000	35.000	30.000
c_2	-----	50.000	45.000	40.000	35.000
x_1^S	2.500	3.000	3.250	3.500	3.750
x_2^S	-----	1.000	1.125	1.250	1.375
π_1^S	62.500	45.000	52.813	61.250	70.313
π_2^S	-----	10.000	12.656	15.625	18.906

In period 4, $\pi_1^D = 75 > \pi_1^S = 61.25$. That is, in period 4, firm 1's profit when it deters entry exceeds its profit when it allows entry.

In period 5, $\pi_1^D = 100 > \pi_1^S = 70.313$. The profit difference between π_1^D and π_1^S of period 5 is 29.687 and is larger than that between π_1^D and π_1^S of period 4.

In this case, we can see that it is a mistake for firm 1 to decide whether to deter or to allow entry by firm 2 on the basis of short-term profit maximization. In other words, firm 1's entry-deterrence behavior leads to its own mid-/long-term profit maximization.

<u>Case (2)</u>

Table 2 shows both firms' profits for this case. In period 1, firm 1's profit is 62.5. In period 2 of this case, since firm 1 enjoys a pure monopoly, its profit is 75.625.

Table 2. Case 2: Firm 2 attempts to enter the market in period 3

	Period 1	*Period 2*	*Period 3*	*Period 4*	*Period 5*
c_1	50.000	45.000	40.000	35.000	30.000
c_2	-----	-----	-----	-----	-----
x_1^D	2.500	2.750	5.000	5.000	5.000
x_2^D	-----	-----	-----	-----	-----
π_1^D	62.500	75.625	50.000	75.000	100.000
π_2^D	-----	-----	-----	-----	-----
c_1	50.000	45.000	40.000	35.000	30.000
c_2	-----	-----	50.000	45.000	40.000
x_1^S	2.500	2.750	3.500	3.750	4.000
x_2^S	-----	-----	0.750	0.875	1.000
π_1^S	62.500	75.625	61.250	70.313	80.000
π_2^S	-----	-----	5.625	7.656	10.000

In period 3, firm 2 attempts to enter the market. In period 3, $\pi_1^D = 50 < \pi_1^S = 61.25$. If firm 1 adopts the profit maximization behavior in period 3 only, then firm 1 will allow entry by firm 2.

However, in period 4, $\pi_1^D = 75 > \pi_1^S = 70.313$. Furthermore, the profit differences between π_1^D and π_1^S grow as the period advances. Hence, it can be said that firm 1's entry-deterrence behavior leads to its own mid-/long-term profit maximization.

<u>Case (3)</u>

In this case, the demand in the market increases as the period advances, namely, *a* increases by 10 every period. (See Table 3.)

In period 2, a =110, and hence, firm 1's profits for Case (3) are larger than those for Case (1), namely, $\pi_1^D = 30$ and $\pi_1^S = 61.25$. If firm 1 adopts the profit maximization behavior of period 2 only, firm 1 would allow entry by firm 2.

However, in period 5, $\pi_1^D = 180 > \pi_1^S = 165.313$. Though not shown in this table, in period 6, $\pi_1^D = 250 > \pi_1^S = 211.25$, and the profit differences between π_1^D and π_1^S grow further as the period advances. Hence, firm 1 is better off deterring the entry of firm 2 to ensure its own mid-/long-term profit maximization.

<u>Case (4)</u>

As shown in Table 4, in this case, the demand in the market decreases with time, namely, *a* decreases by 10 every period.

In period 2, $a = 90$, $\pi_1^D = 20$, and $\pi_1^S = 31.25$. Hence, if firm 1 bases its profit maximization goal only on period 2, it will allow entry by firm 2. However, in period 3, $\pi_1^D = 30 > \pi_1^S = 25.313$.

As shown in this table, the profit differences between π_1^D and π_1^S grow further as the period advances. If firm 1 adopts the entry-deterrence behavior, then firm 2's entry is blocked in period 5, and firm 1 prevails as a monopoly.

3. Non-linear numerical example

In this section, we examine the utility of entry deterrence by using an inverse demand function that is a little more complex than that of the preceding section. The assumptions remain the same, however. In period 1, firm 1 enjoys a pure monopoly. After that, firm 2 attempts to enter the market. Firm 2 enters the market if, and only if, its post-entry profit is positive. If firm 2 enters the market, then in each post-entry period, first of all, firm 1 chooses its own output, x_1, and after observing x_1, firm 2 chooses x_2. If firm 2 does not enter the market, firm 1 acts as a monopolist.

Table 3. Case 3: Firm 2 attempts to enter the market in period 2 and the market demand increases by 10 every succeeding period

	Period 1	*Period 2*	*Period 3*	*Period 4*	*Period 5*
a	100.000	110.000	120.000	130.000	140.000
c_1	50.000	45.000	40.000	35.000	30.000
c_2	-----	-----	-----	-----	-----
x_1^D	2.500	6.000	7.000	8.000	9.000
x_2^D	-----	-----	-----	-----	-----
π_1^D	62.500	30.000	70.000	120.000	180.000
π_2^D	-----	-----	-----	-----	-----
c_1	50.000	45.000	40.000	35.000	30.000
c_2	-----	50.000	45.000	40.000	35.000
x_1^S	2.500	3.500	4.250	5.000	5.750
x_2^S	-----	1.250	1.625	2.000	2.375
π_1^S	62.500	61.250	90.313	125.000	165.313
π_2^S	-----	15.625	26.406	40.000	56.406

We consider the following inverse demand function:

$$P = \alpha\left(x_1 + x_2\right)^{-1/\beta}, \tag{4}$$

where $\alpha, \beta > 0$. Firm 1's profit is

$$\pi_1 = \left\{\alpha\left(x_1 + x_2\right)^{-1/\beta}\right\}x_1 - c_1 x_1, \tag{5}$$

Table 4. Case 4: Firm 2 attempts to enter the market in period 2 and the market demand decreases by 10 every succeeding period

	Period 1	*Period 2*	*Period 3*	*Period 4*	*Period 5*
a	100.000	90.000	80.000	70.000	60.000
c_1	50.000	45.000	40.000	35.000	30.000
c_2	-----	-----	-----	-----	-----
x_1^D	2.500	4.000	3.000	2.000	1.500
x_2^D	-----	-----	-----	-----	-----
π_1^D	62.500	20.000	30.000	30.000	22.500
π_2^D	-----	-----	-----	-----	-----
c_1	50.000	45.000	40.000	35.000	30.000
c_2	-----	50.000	45.000	40.000	35.000
x_1^S	2.500	2.500	2.250	2.000	1.750
x_2^S	-----	0.750	0.625	0.500	0.375
π_1^S	62.500	31.250	25.313	20.000	15.313
π_2^S	-----	5.625	3.906	2.500	1.406

while firm 2's profit is

$$\pi_2 \begin{cases} \left\{\alpha\left(x_1+x_2\right)^{-1/\beta}\right\}x_2-\left(f_2+c_2x_2\right) & \text{Enter} \\ 0 & \text{Stay Out.} \end{cases} \tag{6}$$

If firm 2 enters the market, then in each post-entry period, firm 1 acts as the Stackelberg leader due to the development of the product, while firm 2 acts as the Stackelberg follower.

In the non-linear numerical example, we assume the following: In period 1, $\alpha = 1{,}000$, $\beta = 2$, $f_2 = 10$, and $c_1 = 30$. If firm 2 enters the market, then $c_2 = 30$ in the entry period. In addition, if firm i ($i = 1{,}2$) continues to produce, as the period advances, its marginal cost decreases by 3 every period due to learning by doing, namely, 30, 27, 24, 21, and so on.

In this section, we apply the same conditions to four cases as in the preceding section, namely:

Case (5): Firm 2 attempts to enter the market in period 2;

Case (6): Firm 2 attempts to enter the market in period 3;

Case (7): Firm 2 attempts to enter the market in period 2 and the amount of demand in the market increases as the period advances, namely, α increases by 200 every period; and

Case (8): Firm 2 attempts to enter the market in period 2 and the amount of demand in the market decreases as the period advances, namely, α decreases by 200 every period.

Case (5)

Both firms' profits for this case are given in Table 5. In period 1, firm 1 enjoys a pure monopoly, and hence, firm 1's output and its profit are 278 and 8,333, respectively.

In period 2, firm 2 attempts to enter the market. If firm 1 deters entry by firm 2, then $x_1^D = 1{,}057$ and $\pi_1^D = 3{,}973$. On the other hand, if firm 1 allows entry by firm 2, then $x_1^S = 587$ and $\pi_1^S = 4{,}662$. Hence, if firm 1 adopts the profit maximization behavior of period 2 only, then firm 1 will allow entry by firm 2.

In period 3, $\pi_1^D = 7{,}144 > \pi_1^S = 5{,}404$. As shown in this table, the profit differences between π_1^D and π_1^S grow further as the period advances. Hence, firm 1's entry-deterrence behavior leads to its own mid-/long-term profit maximization.

Case (6)

As shown in Table 6, in period 2 of this case, firm 1 enjoys a pure monopoly, and hence, firm 1's output and its profit are 343 and 9,259, respectively.

In period 3, firm 2 attempts to enter the market. If firm 1 deters entry by firm 2, then $x_1^D = 1{,}057$ and $\pi_1^D = 7{,}144$. On the other hand, if firm 1 allows entry by firm 2, then $x_1^S = 889$ and $\pi_1^S = 6{,}847$. Hence, in period 3, firm 1's profit when it adopts entry-deterrence behavior exceeds its profit when it allows another firm's entry.

The marginal cost differences between firms 1 and 2 are larger for Case (6) than for Case (5), and therefore, firm 2's output in period 5 becomes zero.

Table 5. Case 5: Firm 2 attempts to enter the market in period 2

	Period 1	*Period 2*	*Period 3*	*Period 4*	*Period 5*
c_1	30	27	24	21	18
c_2	-----	-----	-----	-----	-----
x_1^D	278	1,057	1,057	1,057	1,057
x_2^D	-----	-----	-----	-----	-----
π_1^D	8,333	3,973	7,144	10,315	13,486
π_2^D	-----	-----	-----	-----	-----
c_1	30	27	24	21	18
c_2	-----	30	27	24	21
x_1^S	278	587	758	1,013	1,425
x_2^S	-----	232	274	326	385
π_1^S	8,333	4,662	5,404	6,410	7,845
π_2^S	-----	1,137	1,131	1,085	964

Case (7)

In this case, it is assumed that α increases by 200 every period. In period 2, firm 2 attempts to enter the market, and the corresponding profits for firm 1 are $\pi_1^D = 5{,}570 < \pi_1^S = 6{,}716$. (See Table 7.)

In period 3, $\pi_1^D = 13{,}739 > \pi_1^S = 10{,}599$. As shown in this table, the profit differences between π_1^D and π_1^S increase with time. Hence, firm 1's entry-deterrence behavior would support its goal of mid-/long-term profit maximization.

Table 6. Case 6: Firm 2 attempts to enter the market in period 3

	Period 1	*Period 2*	*Period 3*	*Period 4*	*Period 5*
c_1	30	27	24	21	18
c_2	-----	-----	-----	-----	-----
x_1^D	278	343	1,057	1,057	1,057
x_2^D	-----	-----	-----	-----	-----
π_1^D	8,333	9,259	7,144	10,315	13,486
π_2^D	-----	-----	-----	-----	-----
c_1	30	27	24	21	18
c_2	-----	-----	30	27	24
x_1^S	278	343	889	1,211	1,736
x_2^S	-----	-----	106	79	0
π_1^S	8,333	9,259	6,847	8,286	10,417
π_2^S	-----	-----	180	67	0

Case (8)

As seen in Table 8, this case assumes that α decreases by 200 every period. In period 2, firm 2 attempts to enter the market, and $\pi_1^D = 2{,}641 < \pi_1^S = 2{,}993$. Hence, if firm 1 pursues profit maximization based on period 2 results only, it will allow entry by firm 2.

However, in period 3, $\pi_1^D = 2{,}678 > \pi_1^S = 1{,}941$. Furthermore, in periods 4 and 5, firm 1 gains more profit when it adopts the entry-deterrence behavior than when it allows another entrant to the market.

Though not shown in the table, $\alpha = 0$ in period 6. Hence, period 5 marks the end for this market. Firm 1's profits from period 1 to period 5 when it adopts the entry deterrence behavior total 15,921, while its corresponding profits when it allows the entry amount to 14,613.

Table 7. Case 7: Firm 2 attempts to enter the market in period 2 and the market demand increases by 200 every succeeding period

	Period 1	*Period 2*	*Period 3*	*Period 4*	*Period 5*
α	1,000	1,200	1,400	1,600	1,800
c_1	30	27	24	21	18
c_2	-----	-----	-----	-----	-----
x_1^D	278	1,535	2,102	2,758	3,503
x_2^D	-----	-----	-----	-----	-----
π_1^D	8,333	5,570	13,739	26,109	42,549
π_2^D	-----	-----	-----	-----	-----
c_1	30	27	24	21	18
c_2	-----	30	27	24	21
x_1^S	278	845	1,484	2,596	4,617
x_2^S	-----	334	537	834	1,249
π_1^S	8,333	6,716	10,599	16,405	25,402
π_2^S	-----	1,643	2,224	2,768	3,125

Clearly, it will be to firm 1's benefit to adopt the entry-deterrence behavior rather than allowing the entry of another firm.

In the case where such a market disappears, firm 1's decision to allow another firm's entry supports the objective of profit maximization. We can see this to be the logical move for firm 1 when the market disappears in period 3.

However, since it is generally believed that the market will long continue, it can be said that the firm's entry-deterrence behavior promotes profit maximization and leads to the continued existence of the firm, which is an ultimate target.

Table 8. Case 8: Firm 2 attempts to enter the market in period 2 and the market demand decreases by 200 every succeeding period

	Period 1	*Period 2*	*Period 3*	*Period 4*	*Period 5*
α	1,000	800	600	400	200
c_1	30	27	24	21	18
c_2	-----	-----	-----	-----	-----
x_1^D	278	668	368	157	34
x_2^D	-----	-----	-----	-----	-----
π_1^D	8,333	2,641	2,678	1,715	554
π_2^D	-----	-----	-----	-----	-----
c_1	30	27	24	21	18
c_2	-----	30	27	24	21
x_1^S	278	375	273	162	57
x_2^S	-----	148	99	52	15
π_1^S	8,333	2,993	1,941	1,028	318
π_2^S	-----	727	407	174	39

4. Conclusion

We have examined numerical examples in which the firms' marginal costs decrease due to learning by doing. Moreover, we have shown the importance of entry deterrence by using the numerical examples.

In the case where an incumbent firm faces a potential entrant, its short-term profit maximization behavior is not necessarily a good policy. In other words, if the incumbent firm deviates from short-term profit maximization behavior and deters entry by the potential entrant, then the mid-/long-term profit maximization of the incumbent firm is achieved. In effect, this strategy assures the continued existence of the firm, which is the ultimate objective.

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