E C O N O M I C S   B U L L E T I N

The Learning Curve and Durable−Goods Production

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Abstract

We investigate the effect of a learning curve on the production of durable goods by examining a durable−goods monopolist in a two−period model. If the monopolist faces a learning curve, the model shows that the equilibrium quantity of the first− (second−) period products will be smaller (larger) than if there were no learning curve. Consequently, in cases where the original production cost is sufficiently large, the presence of a learning curve drives down total profits.

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1. Introduction

The purpose of this paper is to investigate the effect of a learning curve on the production of durable goods.

There is said to be a learning effect if experienced producers have detailed knowledge allowing them to decrease production cost.[1] Economies of scale are realized if mass production in a "certain" period reduces that period's production cost. In contrast, when there is a learning effect, it is the "cumulative" quantity of the products that reduces the production cost, which is denoted by a learning curve.

We analyze the effect of a learning curve on the production of durable goods by using a two-period model of durable-goods monopolist.[2] If a learning curve is introduced in a two-period model, the quantity of the first-period products affects the second-period production cost. In the case of non-durable goods, the existence of a learning curve increases the quantity of products in not only the first period but also the second period. Namely, the producer will intentionally increase the quantity of the first-period products so as to reduce the second-period production cost, which in turn stimulates production activities in the second period.

On the other hand, there is a "commitment problem" in the production of durable goods.[3] Therefore, we would expect that the effect of a learning curve on the production of durable goods to be different from that of a learning curve on the production of non-durable goods.[4] This paper examines this difference by using a durable-goods monopolist's model.

2. The Model

Here, we investigate the effect of a learning curve on the durable-goods producer's behavior.

Rental demand functions of durable goods at the first and second period are

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[1] For an analysis of duopoly competition with a learning curve, see Spence (1981), and Fudenberg and Tirole (1983). Majd and Pindyck (1989) show the implication of a learning curve under uncertainty. See Cabral and Riordan (1994) for the effect of a learning curve on predatory pricing.

[2] See Bulow (1982) concerning the durable-goods monopolist's model.

[3] On the commitment problem, see Bulow (1982), Waldman (1996), and Utaka (2000).

[4] Olsen (1992) investigates the validity of the Coase conjecture in the production of durable goods with a learning curve. In this paper, we examine the effect of the learning curve on the equilibrium results.

denoted as

$$r_1 = a - bq_1\,, \tag{1}$$

$$r_2 = a - b(q_1 + q_2)\,, \tag{2}$$

where q_i represents the quantity of products, and r_i (i=1 or 2) the rental price of period i.

We assume that durable goods do not depreciate physically, and the discount factor is 1. The marginal cost of producing durable goods in the first period is c. Moreover, we assume that the larger the quantity of first-period products, the smaller the second-period production cost, namely,

$$c_2 = c_2(q_1)\ (c_2' < 0).$$

We specify this function as follows:

$$c_2(q_1) = c - eq_1. \tag{3}$$

In other words, the second-period production cost is a linear decreasing function of the quantity of first-period products.

We investigate the subgame-perfect Nash equilibrium. At first, let us analyze the monopolist's behavior in the second period. The monopolist's problem becomes as follows:

$$\max_{q_2} \pi_2 = q_2\{a - b(q_1 + q_2)\} - (c - eq_1)q_2\,. \tag{4}$$

From the first order condition, we obtain

$$q_2 = \frac{a - c - q_1(b - e)}{2b}\,. \tag{5}$$

Therefore, the monopolist's problem in the first period can be expressed as follows:

$$\max_{q_1} \pi = q_1 r_1 + q_1 r_2 + q_2 r_2 - c q_1 - (c - e q_1) q_2$$

$$= q_1 (a - b q_1)$$

$$+ \left(q_1 + \frac{a - c - q_1 (b - e)}{2b} \right) \left(a - b q_1 - b \cdot \frac{a - c - q_1 (b - e)}{2b} \right) \tag{6}$$

$$- c q_1 - (c - e q_1) \cdot \frac{a - c - q_1 (b - e)}{2b}.$$

From the first order condition of this problem, the equilibrium quantity of the first-period products becomes

$$\tilde{q}_1 = \frac{2ab + e(a - c)}{5b^2 + 4be - e^2}. \tag{7}$$

By substituting (7) into (5), we obtain

$$\tilde{q}_2 = \frac{3ab - 5bc + e(5a - 3c)}{2(5b^2 + 4be - e^2)}. \tag{8}$$

From (7) and (8), we obtain the following theorem.

Theorem 1

If the monopolist faces a learning curve, the equilibrium quantity of the first (second) period products becomes smaller (larger) than if there were no learning curve.

Proof

See Appendix 1.

Since the existence of a learning curve reduces the second-period production cost, the quantity of the second-period products becomes larger, which inevitably decreases the value of the first-period products. Therefore, the monopolist determines to lower the production level in the first period.

Next, by considering (4), (6), (7), (8), and theorem 1, we obtain the following theorem.

Theorem 2

If the monopolist faces a learning curve, the second-period profits become larger than if there were no learning curve. On the other hand, the total profits become larger (smaller) in cases where $c < (>) \frac{1}{5} a$.

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Proof

See Appendix 2.

Especially, it is worth noting that the existence of a learning curve decreases the total profits as long as the original production cost is large (namely, in cases where $c > \frac{1}{5} a$). The intuition behind this result is as follows. The existence of a learning curve decreases not only the second-period production cost but also the quantity of the first-period products, which leads to the excessive production in the second period (see theorem 1). On the other hand, the decrease in the quantity and price of the first-period products seriously lowers the first-period profits. Therefore, the decrease in the first-period profits exceeds the increase in the second-period profits.

On the contrary, in cases where the original production cost is small, the increase in the second-period profits outweighs the decrease in the first-period profits. This outcome is resulted mainly from the greatly lower cost in the second-period production.

3. Conclusion

We have investigated the effect of a learning curve on the production of durable goods. In the case of non-durable goods, it is known that the existence of a learning curve increases the quantity of products in not only the first period but also second period, which leads to the larger total profits. On the contrary, our paper has shown that the equilibrium quantity of the first-period products becomes smaller.

Concequently, especially in cases where the original production cost is large, the presence of a learning curve drives down the total profits.

The existing empirical studies find out the presence of a learning curve in various sorts of industry (for the case of chemical processing industry, see Lieberman (1984)). However, our paper has shown that in the production of durable goods, the existence of a learning curve can decrease the total profits. Therefore, it is necessary to investigate empirically what effect a learning curve has on the durable-goods producer's profits.

It is noted that our analysis is local one. In other words, we investigate only the case where the learning effect is sufficiently small. Therefore, there is room for investigating the case where the larger learning effect exists.

Appendix 1

Here, we conduct theorem 1. First, from (7), we obtain

$$\frac{d\tilde{q}_1}{de} = \frac{1}{\left(5b^2+4be-e^2\right)^2}\left[(a-c)\left(5b^2+4be-e^2\right)-(4b-2e)\left\{2ab+e(a-c)\right\}\right]$$

$$= \frac{1}{\left(5b^2+4be-e^2\right)^2}\left\{(a-c)e^2+4abe-(5c+3a)b^2\right\}.$$

Therefore, it is shown that

$$\left.\frac{d\tilde{q}_1}{de}\right|_{e=0} = \frac{1}{\left(5b^2\right)^2}\left\{-(5c+3a)b^2\right\} < 0,$$

in other words, if the monopolist has a learning curve, the equilibrium quantity of the first-period products becomes smaller than if there were no learning curve.

Next, from (8), we obtain

$$\frac{d\tilde{q}_2}{de} = \frac{1}{2\left(5b^2+4be-e^2\right)^2}$$
$$\cdot\left[(5a-3c)\left(5b^2+4be-e^2\right)-(4b-2e)\{3ab-5bc+e(5a-3c)\}\right]$$

$$= \frac{1}{2\left(5b^2+4be-e^2\right)^2}\left[13ab^2+5b^2c+e\{6ab-10bc+e(5a-3c)\}\right].$$

Therefore, it follows that

$$\left.\frac{d\tilde{q}_2}{de}\right|_{e=0} = \frac{1}{2\left(5b^2+4be-e^2\right)^2}\left(13ab^2+5b^2c\right) > 0\ .$$

Appendix 2

First, we investigate the effect of a learning curve on the second-period profits. From (4), (7), and (8), it is shown that

$$\tilde{\pi}_2=\tilde{q}_2\left(a-b(\tilde{q}_1+\tilde{q}_2)\right)-(c-e\tilde{q}_1)\tilde{q}_2$$

$$= \frac{3ab-5bc+e(5a-3c)}{2\left(5b^2+4be-e^2\right)}$$
$$\cdot\left\{a-b\frac{2ab+e(a-c)}{5b^2+4be-e^2}-b\frac{3ab-5bc+e(5a-3c)}{2\left(5b^2+4be-e^2\right)}-c+e\frac{2ab+e(a-c)}{5b^2+4be-e^2}\right\}$$

$$= b\left\{\frac{3ab-5bc+e(5a-3c)}{2\left(5b^2+4be-e^2\right)}\right\}^2$$

$$.\ \ = b\cdot(\tilde{q}_2)^2.$$

Therefore, by considering theorem 1, we obtain

$$\left.\frac{d\tilde{\pi}_2}{de}\right|_{e=0} > 0.$$

Next, let us investigate the effect of a learning curve on the total profits. From (6), we obtain

$$\frac{d\pi}{de} = \frac{d\pi}{dq_1}\cdot\frac{dq_1}{de} + \frac{q_1}{2b}\left(a - c + eq_1 - 2bq_1\right).$$

Since $\frac{d\tilde{\pi}}{dq_1} = 0$, it follows that

$$\frac{d\tilde{\pi}}{de} = \frac{\tilde{q}_1}{2b}\left(a - c + e\tilde{q}_1 - 2b\tilde{q}_1\right).$$

By considering $\tilde{q}_1 = \frac{2a}{5b}$ in the case of $e = 0$, we obtain

$$\left.\frac{d\tilde{\pi}}{de}\right|_{e=0} = \frac{a}{25b^2}\left(a - 5c\right).$$

Therefore,

$$\left.\frac{d\tilde{\pi}}{de}\right|_{e=0} > 0 \;(< 0), \text{ in cases where } c < (>) \frac{1}{5}a.$$

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