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ABSTRACT

Learning by Doing, Spillover and Shakeout in Monopolistic Competition

by Horst Albach and Jim Jin*

This paper studies the impact of learning by doing on shakeouts in monopolistic competition. Firms have different initial costs and set prices to maximize current profits in each period. Although all firms make positive profits at the beginning and grow for a certain period of time, shakeouts may occur as costs are reduced through learning by doing and spillovers. We give a necessary condition for shakeouts in terms of the relative effectiveness of proprietary learning and the industry-wide learning. Given this condition, shakeouts are more likely to occur when the learning potential is large, the market is small, the proprietary learning is effective and spillovers are weak. In the absence of any strategic learning or predatory pricing, learning by doing can create significant market barriers.

ZUSAMMENFASSUNG

Lerneffekte, Externalitäten und Marktaustritte bei monopolistischer Konkurrenz

In diesem Aufsatz werden die Auswirkungen von Lerneffekten durch (Produktions-)erfahrung auf Marktaustritte (sog. „shakeouts“) im Kontext monopolistischer Konkurrenz untersucht. Unternehmen haben unterschiedliche Anfangskosten und maximieren ihre laufenden Periodengewinne. Auch wenn zunächst alle Marktteilnehmer Profite erzielen und über einen bestimmten Zeitraum hinweg wachsen, kann es in einem fortgeschrittenen Stadium zu Marktaustritten kommen. Grund dafür ist die Reduktion der Produktionskosten durch Lerneffekte und Externalitäten. Wir zeigen, welche notwendige Bedingung an eigene und industriespezifische Lerneffekte erfüllt sein muß, damit es zu Marktaustritten kommen kann. Ist diese Bedingung erfüllt, sind Marktaustritte um so wahrscheinlicher, je größer das Potential zur Realisierung von Lerneffekten, je kleiner der Markt, je effektiver eigenes Lernen und je geringer der externe Effekt ist. Auch in Abwesenheit von strategischem Lernen und markteintrittsverhindernder Preissetzung können Lerneffekte bedeutende Marktbarrieren begründen.

* We thank Dieter Köster for his valuable work to simulate the model and Hans Mewis for his various comments and suggestions. The responsibility for any remaining errors is authors'.

1. Introduction

In this paper we examine how learning by doing and spillovers create market barriers without incumbents' strategic learning or predatory pricing. Learning by doing, even if not conducted strategically, can significantly reduce the number of viable firms given the market size, product substitutability and initial cost structure. It seems that the most effective way to dismantle such market barriers is to increase spillovers.

Since the seminar work of Arrow (1962), the concept of learning by doing has been an important subject in the economics literature. Empirical studies have found a significantly positive relation between a firm's productivity and its production experience in various industries. Recent studies also showed that firms can learn from others' experience as well as from their own in a wide range of market structures. The examples include Zimmerman (1982) for the nuclear power plants, Lieberman (1989) for the chemical processing industry, Foster and Rosenzweig (1995) for agriculture.

Meanwhile theoretical models suggest that learning by doing has a strong impact on market competition and performance. In a Cournot oligopoly model Spence (1981) argued that proprietary learning gives early entrants cost advantages and creates entry barriers. He also discussed the impact of spillovers in a two period model. More rigorously, Fudenberg and Tirole (1983) showed in a two period Cournot duopoly that spillovers reduce firms' incentives for strategic learning. Further, Ghemawat and Spence (1985) demonstrated with a symmetric Cournot oligopoly that spillovers substantially undercut the entry barriers created by learning. In all these models learning by doing blocks entry ex ante since rational firms do not enter if they can not make profits or survive in the market.

In the real world firms can not fully anticipate their success or failure before entry. Shakeouts are often a common feature during the early stage of market evolution (see Gort and Klepper 1982). In particular firms may exit having enjoyed positive or even increasing profits before declining into non-existence. Learning by doing may explain this phenomena of post-entry selection. Cabral and Riordan (1994) demonstrated how an early entrant can build up its dominant position through learning by doing and set predatory prices in a differentiated Bertrand duopoly. In a two period perfectly competitive model Petrakis, Rasmusen and Roy (1997) recently showed learning by doing may force some firms to exit the market despite their experience gained earlier. Also in perfectly competition Jovanovic and Lach (1989) studied the impact of learning by doing on technology diffusion, which is modeled as entry of new machines and exit of old ones.

Not all plausible features of shakeouts, however, have been included in the previous models. First of all, new firms may not be blocked from entry right away, or may not be driven out of the market in two periods, but survive a substantial time before the exit. Secondly, instead of duopoly and perfect competition, the number of firms may be rather large. Finally, because of a long time horizon and many competitors, firms may not be perfectly rational to strategically gain production experience through learning by doing. While the existing models illustrate the strategic learning by rational firms, they may overlook the complexity of the industry evolution over a longer time with many non-strategic firms.

To complement the existing theory of learning by doing, this paper describes a shakeout process due to learning by doing and shakeouts in monopolistic competition. It considers how shakeouts occur after entrants have entered a market for sometime and gained production experience. The entry barriers created by learning are different from the existing models. First, instead of blocking entry ex ante, the entrants may be doing well for a long time before they decline and eventually exit the market. Secondly the entrants may be driven out of the market without any strategic maneuver of the incumbents, such as predatory pricing or strategic learning. This is more likely to happen in monopolistic competition since firms are not fully rational and proprietary learning may be negligible relative to the industry-wide learning because of a single firm's tiny market share.

Needless to say that a general model would exclude any clear-cut solution. Facing the usual trade-off for economists we use a simple linear demand and learning model to describe a multi-period dynamic process of individual and the industry outputs. We find a necessary condition for shakeouts in terms of the relative effectiveness of proprietary learning and spillovers. Given this condition shakeouts are more likely when the market is smaller, the number of firms is larger and learning is more proprietary. Given the demand and cost structures, learning by doing can significantly reduce the number of viable firms, as argued earlier by Albach (1995).

The paper is organized as follows: Section 2 introduces the model. Section 3 solves the dynamic process of firms' outputs and costs, and gives the shakeout conditions. The impacts of the cost structure, demand function and effectiveness of learning are analyzed in Section 4, which is followed by the concluding remarks in the last section.

2. Model

There is a n-firm monopolistically competitive market with n differentiated (substitute) goods and a competitive market with a numeraire good whose price is normalized to 1. Denote firms i's output in period t by x_{it} and the n×1 output vector by $\mathbf{x}_t$. Assume that the representative consumer has a fixed income y and a quadratic utility function all the time:

$$u(x_{0t},\mathbf{x}_t) = x_{0t} + a\sum_{i=1}^{n} x_{it} - 0.5\sum_{i=1}^{n} x_{it}^2 - r\sum_{i=1}^{n}\sum_{j\neq i}^{n} x_{it}x_{jt} \qquad (1)$$

where a > 0 and 0 < r < 1. When r approaches 1, the product substitutability becomes perfect; while r = 0 implies independent products. Denote firm i's price in period t by p_{it} and the n×1 price vector by $\mathbf{p}_t$. Given $\mathbf{p}_t$ and his budget constraint $x_{0t} + \mathbf{p}_t\cdot\mathbf{x}_t \leq y$, the representative consumer chooses x_{0t} and $\mathbf{x}_t$ to maximize his utility (1). Since the utility function is strictly concave in $\mathbf{x}_t$, the optimal consumption can be solved from the following first-order condition:

$$p_{it} = a - x_{it} - r\sum_{j\neq i}^{n} x_{jt} \qquad (2)$$

From (2) we can solve firm i's demand function in period t as:

$$x_{it} = \frac{1}{(1-r)[1+(n-1)r]}\{(1-r)a - [1+(n-2)r]p_{it} + r\sum_{j\neq i}^{n} p_{jt}\} \qquad (3)$$

Let c_{it} denote firm i's marginal cost in period t. In every period t each firm i chooses p_{it} to maximize its current profit $x_{it}(p_{it}-c_{it})$, where x_{it} is given by (3). We assume that firms do not strategically make use of the opportunity of learning by doing given the limited rationality. As every firm's profit function is strictly concave in its price, the market equilibrium in monopolistic competition can be solved by the following first-order condition:

$$(1-r)a - 2[1+(n-2)r]p_{it} + [1+(n-2)r]c_{it} + r\sum_{j\neq i}^{n} p_{jt} = 0 \qquad (4)$$

Assume that learning by doing and spillovers reduces every firm i's marginal cost linearly in its own accumulated output and the industry accumulated output. Let $\sum_{\tau=1}^{t-1} x_{i\tau}$ be firm i's accumulated output from period 1 to t -1, and $\sum_{\tau=1}^{t-1}\sum_{i=1}^{n} x_{i\tau}$ be the accumulated industry output during the same time. To simplify notation, denote firm i's initial marginal cost in the first period by c_i. Then its marginal cost in period t (> 1) can be written as follows:

$$c_{it} = c_i - \alpha\sum_{\tau=1}^{t-1} x_{i\tau} - \beta\sum_{\tau=1}^{t-1}\sum_{i=1}^{n} x_{i\tau} \qquad (5)$$

where α and $\beta \geq 0$. β indicates the cost reduction due to one unit of the industry output, α is the cost reduction due to one unit of a firm's own production experience not shared by other firms. In the R&D literature the spillover coefficient is usually defined as one firm's cost reduction due to another firm's one unit cost reduction by its own R&D. Similarly our spillover coefficient θ would be $\beta/(\alpha+\beta)$. When $\alpha = 0$, every firm learns equally from any other firm's production experience, $\theta = 1$, spillovers are perfect. If $\beta = 0$, $\theta = 0$, learning by doing is proprietary. The learning process continues till the cost falls to a minimum level $\underline{c} \geq 0$.

We rank firms according to their efficiencies, i.e. $c_{i+1} \geq c_i$ for all $i < n$. Firm 1 is the most efficient firm and firm n is the most inefficient one. We assume that every firm can produce something in the first period. Shakeouts occur when some firms exit a market a certain period after their entry. Obviously this can only occur before all firms reach the minimum cost $\underline{c}$, i.e. during the phase of learning by doing. In each period firms realize their cost reduction from the last period and choose new prices given new costs. (3), (4) and (5) define a dynamic interaction among all firms' costs, prices and outputs in all periods given initial costs. The dynamic process goes on till either some firms reach the minimum cost or some exit the market. Our model will characterize a necessary and a sufficient condition for shakeouts and evaluate the impact of the cost structure, the demand function and the effectiveness of learning on shakeouts.

3. Industry dynamics

We first solve (4) to get the equilibrium price in t period as

$$p_{it} = \frac{(1-r)a}{2+(n-3)r} + \frac{[1+(n-2)r]c_{it}}{2+(2n-3)r} + \frac{r[1+(n-2)r]}{[2+(n-3)r][2+(2n-3)r]}\sum_{j=1}^{n} c_{jt} \qquad (6)$$

Substituting (6) into (3), we can solve firm i's equilibrium output. To simplify the notation, we define two positive constants as:

$$\phi \equiv \frac{1+(n-2)r}{[1+(n-1)r][2+(n-3)r]}$$

$$\sigma \equiv \frac{r[1+(n-2)r]}{(1-r)[2+(2n-3)r]}$$

Plugging them into the expression of firm i's equilibrium output in period t, we have

$$x_{it} = \phi[a + \sigma\sum_{j=1}^{n}c_{jt} - (1+n\sigma)c_{it}] \qquad (7)$$

To ensure that firm n's output is positive in the first period, (7) implies that the following inequality must hold:

$$[1+(n-1)\sigma]c_n < a - \sigma\sum_{j=1}^{n-1}c_j \qquad (8)$$

Otherwise, the most inefficient firm n cannot enter the market at all and its shakeout is out of the question. This could be the case when incumbents have gained enough cost advantages through learning by doing and block new entry, as discussed by the previous models. Here we only consider the case where (8) holds.

Given (5), we can rewrite firm i's marginal cost in period t as

$$c_{it} = c_{it-1} - \alpha x_{it-1} - \beta\sum_{i=1}^{n}x_{it-1} \qquad (9)$$

(7) describes every firm's output as a function of all firms' current costs, and (9) relates every firm's current cost to its previous cost and all firms' outputs in the last period. These two equations (7) and (9) together present the dynamic process of the market evolution. From them we can solve the path of any firm i's output and its cost before the most efficient firm 1 reaches the minimum cost $\underline{c}$ or the least efficient firm n exits the market. Denote the industry average marginal cost in the first period, $\sum_{i=1}^{n}c_i/n$, by c. Our result can be given as

Proposition 1: Before any firm exhausts its learning potential or exits the market, firm i's cost and output in period t (≥ 1) can be described as follows:

$$c_{it} = a - (a-c)[1+\phi(\alpha+n\beta)]^{t-1} - (c-c_i)(1+\alpha\sigma/r)^{t-1} \qquad (10)$$

$$x_{it} = \phi(a-c)[1+\phi(\alpha+n\beta)]^{t-1} + \phi(c-c_i)(1+n\sigma)(1+\alpha\sigma/r)^{t-1} \qquad (11)$$

Proof: see Appendix A.

Summing up (11) for all i, we get the industry output in period t as

$$\sum_{i=1}^{n}x_{it} = \phi(a-c)[1+\phi(\alpha+n\beta)]^{t-1} \qquad (12)$$

The industry output increases at a constant rate $\phi(\alpha+n\beta)$. Every firm's output have two parts with different growth rates. One is identical for all firms and grows at the same pace as the industry does, the other reflects a firm's cost advantage/disadvantage due to its initial cost. The industry growth rate, $\phi(\alpha+n\beta)$, depends on both α and β, while the individual growth rate, $\alpha\sigma/r$, only depends on α. For those firms whose costs are lower than the average c, both parts are positive and their outputs always increase. For the other firms including firm n, the second part is negative and potentially can dominate the first. When this happens, firm n must be the first to exit the market. (10) and (11) are valid up to either firm 1's cost falls to $\underline{c}$ or firm n's output falls to zero.

From (10) and (11) we can easily obtain the cost and output differences between any two firms as

$$c_{it} - c_{jt} = (c_i - c_j)(1+\alpha\sigma/r)^{t-1} \tag{13}$$

$$x_{it} - x_{jt} = \phi(c - c_i)(1+n\sigma)(1+\alpha\sigma/r)^{t-1} \tag{14}$$

The differences increase over time as long as $c_{1t} > \underline{c}$ and $x_{nt} > 0$. So the inefficient firms' cost disadvantage becomes larger and larger during the learning phase. However, as its own cost also decreases over time, whether its output will fall to zero depends on which of these two trends is stronger. Dividing firm i's output in (11) by the industry output in (12), we give firm i's market share in period t as

$$s_{it} = \frac{1}{n} - (1+n\sigma)\frac{c_n - c}{n(a-c)}\left[\frac{1 + \alpha\sigma/r}{1+\phi(\alpha+n\beta)}\right]^{t-1} \tag{15}$$

By the definition of σ and ϕ, $\alpha\sigma/r > \phi(\alpha+n\beta)$ if and only if $\alpha\sigma > \beta$. The inequality means that proprietary learning is significant relative to industry-wide learning. Then the ratio $(1+\alpha\sigma/r)/[1+\phi(\alpha+n\beta)]$ is less than 1. The absolute value of the second term of (15) falls over time, and every firm's market share converges to 1/n. When $\alpha\sigma = \beta$, all firms' market shares remain constant. In either cases no shakeout could occur.

Hence, shakeouts never occur if $\alpha\sigma < \beta$. Given α and β, one can check that the inequality is more likely to hold when the number of firms or the substitutability decrease because σ rises in n and r. In terms of the spillover coefficient θ, it is easy to see that the inequality is guaranteed if $\theta \geq r/(2-r)$. The more substitutable the products are, the more spillovers we need to guarantee firms' survival.

When $\alpha\sigma > \beta$, the second term of (12) grows faster than the first one. The output of the least efficient firm n may increase initially and start falling afterwards. When the second term eventually exceeds the first, its output becomes zero and the shakeout occurs. Then firm n - 1 becomes least efficient. A new process starts again with the new initial costs and more shakeouts may occur. Since the new process also follows (10) and (11), we need only consider firm n's survival. After firm 1 reaches its minimum cost, other firms' costs continue to fall and the danger for firm n's exit still exists. But as firm 1's output starts falling, the pressure on firm n is somehow reduced. To keep our analysis simple, we focus on shakeouts when no firm has exhausted its learning potential. Hence the question is whether firm n's output shrinks to zero before firm 1's cost reaches its minimum $\underline{c}$. We need to find out that under which condition this happens. This is a sufficient condition for shakeouts. It would be a necessary condition too, if all firms except for firm n have the same cost.

Let T denote the time when firm 1's cost reaches $\underline{c}$. From (10) the value of T can be determined by the following condition:

$$(a-c)[1+\phi(\alpha+n\beta)]^{T-1} + (c-c_1)(1+\alpha\sigma/r)^{T-1} = a - \underline{c} \qquad (16)$$

As the left hand side of (16) is monotonically increasing in T, there is a unique solution for T given parameters c_1, c_n, c, $\underline{c}$, a, n, r, α and β.

Given $\alpha\sigma > \beta$, if $x_{nt'} > 0$, we know that $x_{nt} > 0$ for all $t < t'$. Thus firm n's danger of exit increases over time. From (11) we know that firm n cannot survive up to period T if

$$(c_n-c)\left[\frac{1 + \alpha\sigma/r}{1+\phi(\alpha+n\beta)}\right]^{T-1} > \frac{a - c}{1+n\sigma} \qquad (17)$$

where T is determined by (16). Hence we can give the following result.

Proposition 2: A necessary condition for shakeouts is that spillovers are weak relatively to the proprietary learning ($\beta < \sigma\alpha$). A sufficient condition is that (17) holds.

If no shakeout occurs, firms reach the minimum cost one after another. A firm's output starts to fall after its cost reaches $\underline{c}$, as other firms' costs continue to fall. The other firms keep growing till they catch up with the more efficient ones. Eventually all firms share the market equally. The final production cost is the same either shakeouts occur or not. In terms of the long run social efficiency, however, no shakeout implies a higher industry output and social welfare in the long run. In such a case, the efficiency gain associated with fewer firms due to learning by doing and initial cost advantages is temporary. The long run social loss cannot be prevented by conventional competition policies because no behavior of restraint of trade is involved, such as predatory pricing or strategic learning. To ensure the long run competitiveness we need something different from usual antitrust policies. For this purpose we now consider how the sufficient condition (17) is affected by the parameters of the model.

4. Impact of cost, demand and effectiveness of learning

We now consider the impacts of our parameters on the likelihood of shakeouts. The parameters can be divided into three categories regarding the cost structure (c_1, c_n, c, $\underline{c}$), the demand function (a, n, r) and the effectiveness of learning (α, β). We will see how each of them affects the likelihood of shakeouts by using the conditions (16) and (17).

The impacts of cost parameters on shakeout can be seen intuitively. For instance, when firm n's inefficiency is more significant (higher c_n given c_1 and c), it faces more disadvantages all the time. Similarly, when the other firms are more efficient (lower c_1 or c given c_n), they produce more and firm n produces less in every period. Thus firm n's cost disadvantage is bigger and the chance to survive is slimmer. When the learning potential is larger (lower $\underline{c}$). It prolongs the learning period and also increases the possibility of shakeouts.

When the initial costs are symmetric, i.e. $c_n = c$, (17) never holds and all n firms can survive. Firm n cannot survive if the costs are sufficiently asymmetric, i.e. $c_n - c$, is bigger than a certain value. We call this critical value the viable cost disadvantage for firm n. Without learning by doing, (8) implies that firm n can survive if $c_n - c > (a-c)/(1+n\sigma)$. Comparing with (17), we know that with learning by doing, the viable initial cost disadvantage, $c_n - c$, falls by a proportion of $[1+\phi(\alpha+n\beta)]^{T-1}/(1+\alpha\sigma/r)^{T-1}$. From (16) we see that as $\underline{c}$ falls, T must increase to keep (16) valid. So the viable initial cost disadvantage falls more. This implies

Corollary 1: Learning by doing reduces the viable initial cost disadvantage for the inefficient firm. The reduction is more significant when the learning potential is bigger.

For the demand parameters, the impact of the product substitutability seems intuitive. When products are more substitutable (larger r), competition is fiercer for any given costs. Prices are lower, outputs are higher in each period, and the cost differences between efficient and inefficient firms are larger. Hence learning by doing gives more advantages to efficient firms and the chance of shakeouts increases.

But the impacts of the market size and the number of firms are not intuitively clear. When the market is larger (a is bigger), all firms produce more for any given costs. So firms learn more quickly. Cost differences may become larger which increases the chance of shakeouts. On the other hand, however, the inefficient firms have a better chance to survive when the market is larger given the same cost differences. The overall effect of a larger market on shakeouts is unclear. The ambiguity also exists for the number of firms. When the number n is large given the initial cost structure, it is more difficult for the least efficient firm to survive. Nevertheless, every firm produces less in each period and learns more slowly when there are more firms. As every firm's market share decreases, the industry-wide learning becomes more significant relative to the proprietary learning. Hence the learning advantages of efficient firms may be smaller and the overall effect on shakeouts is not known. The ambiguity can be resolved using (16) and (17) to evaluate the impact of a and n. We find

Corollary 2: The shakeout is more likely to occur if the market is smaller or the number of firms is larger.

Proof: see Appendix B.

Figure 1

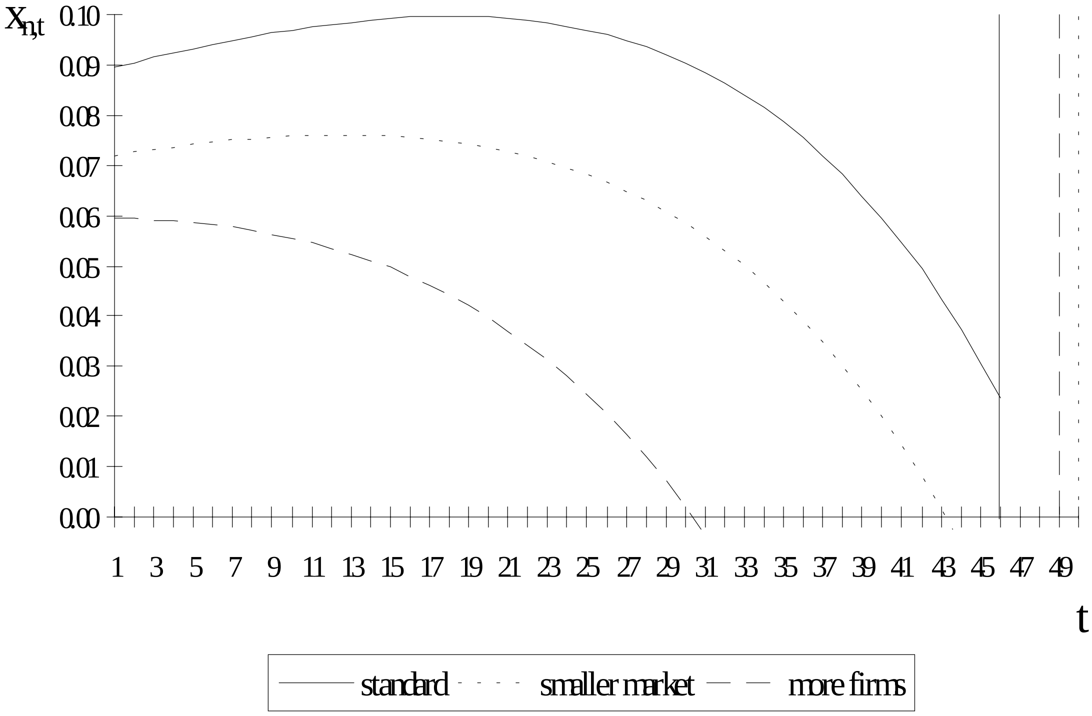


Figure 1 illustrates the impact of a larger market size and a larger number of firms. To keep our simulation simple, we assume a small n = 3. The solid curve indicates the output path of the inefficient firm when its initial cost is 0.67 and the other 2 firms' costs are 0.64. The other parameters are chosen as $\underline{c} = 0$, a = 1, r = 0.75, $\alpha = 0.03$ and $\beta = 0.01$. The vertical line indicates the time when 2 efficient firms reach the minimum cost calculated according to (16) (period 46). Since firm 3's output is still positive at that time, it can survive and no shakeout occurs. The short dashed-curve is drawn under the same conditions except for a smaller market (a = 0.95). Firms produce less and learn more slowly in a smaller market. Consequently the inefficient firm's output falls to zero (period 43) before other firms reach their minimum costs. The shakeout occurs. The long dashed-curve differs from the standard one only in 3 efficient firms instead of 2. The output of the inefficient firm is significantly lower and falls to zero (period 30) well before its rivals exhaust their learning potentials. Comparing with the standard case, we see that the market allows just 3 firms to survive eventually.

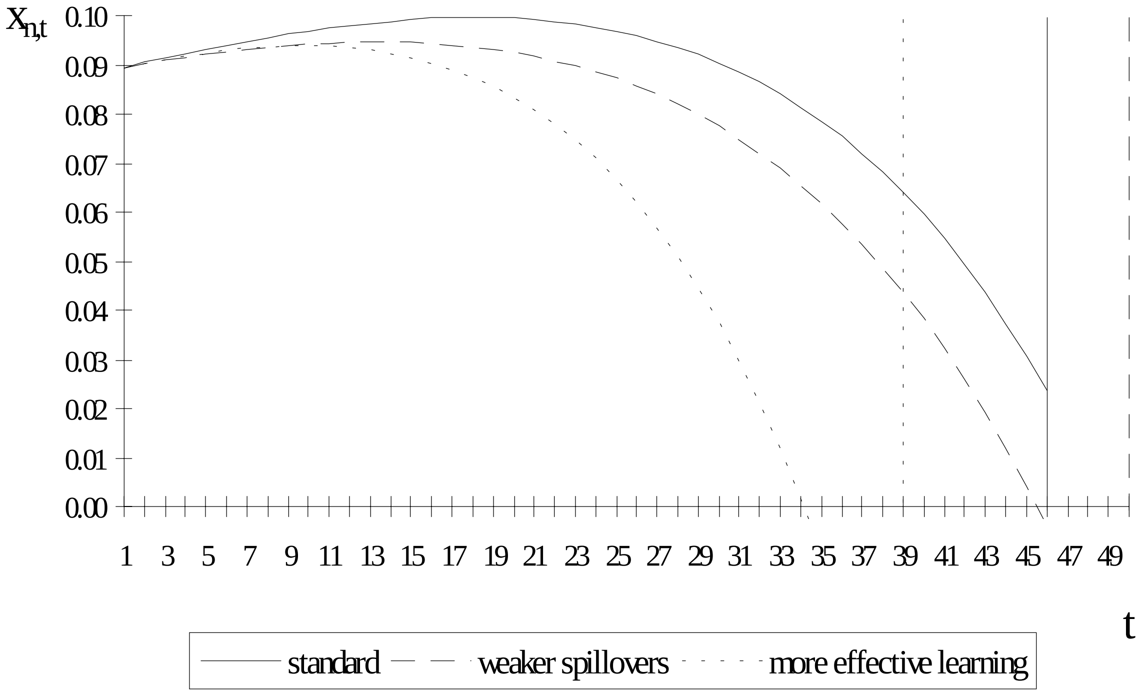
As we mentioned earlier, without learning by doing, the most inefficient firm n cannot survive if c_n - c > (a - c)/(1+nσ). This inequality holds when n is sufficiently large. With learning by doing, (17) can be valid for a smaller n because of the additional term $(1+\alpha\sigma/r)^{T-1}/[1+\phi(\alpha+n\beta)]^{T-1}$. It means that the number of viable firms is reduced because of learning by doing. As we argued earlier that the value of the additional term is larger when $\underline{c}$ is lower, the reduction of the number of viable firms is more significant when the learning potential is larger.

We now consider the impacts of the effectiveness of proprietary and industry-wide learning. When the proprietary learning is more effective, the more efficient firms have bigger advantages for one period learning. But in the next period the low costs resulted from learning lead to a higher industry output, which benefits the inefficient firm through spillovers. Thus in a multi-period dynamic model the more effective proprietary learning may actually benefit the inefficient firm. Similarly, if the industry-wide learning becomes more effective, the advantage of more efficient firms may be weakened. On the other hand, all firms learn faster, cost differences may increase faster and make shakeouts more likely. The ambiguities can be resolved by (16) and (17). We can show that shakeouts are more likely when α is larger or β is smaller. Hence we have

Corollary 3: The shakeout is more likely if proprietary learning is more effective, or spillovers are weaker.

Proof: see Appendix C.
Figure 2 demonstrates the impacts of the effectiveness of learning. The solid curve represents the same standard case as before. The short dashed-curve reflects more effective proprietary learning (α = 0.04). When all firms learn faster from their own production experience, the inefficient firm's output falls to zero (period 34) before the efficient firms could reach the minimum cost (period 39). The long dashed-curve shows the impact of weaker spillovers (β = 0.008). As every firm learns more slowly, the shakeout occurs in period 45 before the efficient firms could go down to the bottom of the learning curve (period 49).

Figure 2



Knowing the impact of every parameter on shakeouts, one can think of a policy instrument to ensure the competitiveness of an industry. Among all the parameters we have discussed, the spillover effect is easiest to be changed by policies, such as encouraging information flow, relaxing patent protection and so on. When β increases and $\alpha + \beta$ remains constant, α must decreases the same amount as β rises, but the spillover coefficient rises. According to Corollary 3, more firms can survive and the market becomes more competitive in the long run. Further, as $\alpha + n\beta$ increases, (12) implies that the industry output grows faster. Thus the social welfare rises during the learning phase. However, an increases in β while keeping $\alpha + \beta$ constant implies that firms' proprietary knowledge is not repetitious so that the total cost reduction is significantly improved by sharing production experience. In the worst case of repetitious knowledge, the total cost reduction remains the same as proprietary learning is converted into public knowledge. This means $\alpha + n\beta$ remains constant while β rises and α falls. Even in this case, shakeouts are still less likely, the industry growth does not change. Hence more spillovers are socially optimal both in terms of the industry growth and in terms of the competitiveness of the eventual market structure.

5. Concluding remarks

This paper describes a dynamic process of a monopolistically competitive market with learning by doing and spillovers. We examine the possibility of new entrants' survival without strategic learning or predatory pricing. We found that even though a new firm enter a market successfully at the beginning and grows for a certain period of time, its eventual survival is not guaranteed. Shakeouts occur when learning by doing creates sufficient cost advantages for efficient firms such that inefficient firms have to exit the market even though their costs have been reduced through production experience. This is possible only if spillovers are weak relative to the proprietary learning ($\beta < \sigma\alpha$). When this condition is satisfied, whether shakeouts occur depend on three aspects of the market competition: the cost structure, the demand function and the effectiveness of learning. In particular we found that learning by doing significantly reduces the viable initial cost disadvantage for inefficient firms. Shakeouts are more likely to occur when the market is smaller, the number of firms is larger, the proprietary learning is more effective and spillovers are weaker.

The main message of the paper is that learning by doing can create significant market barriers without any strategic actions of incumbents. Compared with the no shakeout case, the long run industry output and social welfare are lower. Although in the short run shakeouts are consistent with "fair competition" in production efficiencies, it may not be socially optimal to allow these temporary cost advantages to become permanent privileges. To dismantle the barriers created by learning by doing and promote the long run efficiency, it seems that the most effective way is to enhance the effectiveness of industry-wide learning or spillovers. This is especially true when individual learning will not be discouraged by strong spillovers, such as in monopolistic competition.

To solve the industry dynamics, we made a couple of simplifying assumptions. We assume that the learning process is linear till the minimum cost is reached. It would be more appropriate that the learning curve approaches the limit gradually due to diminishing returns. But this will exclude a simple dynamic solution. Furthermore we abstract from any active R&D. Doing so might obscure the effects of learning by doing. At the same time it might be a promising way to enrich the model. In the present model it is always the smallest firm that exits the market and no firm can leapfrog others. The introduction of R&D would eliminate this limitation and might be worthwhile for our future research.

REFERENCES:

Albach, H., *Global Competitive Strategies for Scienceware Products*, WZB 1995

Arrow, K., 1962, The Economic Implications of Learning by Doing, *Review of Economic Studies* **29**: 155-173

Cabral, L. and M. Riordan, 1994, The Learning Curve, Market Dominance, and Predatory Pricing, *Econometrica* **62**: 1115-1140

Foster, A. and M. Rosenzweig, 1995, Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture, *Journal of Political Economy* **103**: 1176-1209

Fudenberg, D. and J. Tirole, 1983, Learning-by-doing and Market Performance, *Bell Journal of Economics* **14**: 522-530

Ghemawat, P. and M. Spence, 1985, Learning curve Spillovers and Market Performance, *Quarterly Journal of Economics* **100**: 839-852

Gort, M. and S. Klepper, 1982, Time Paths in the Diffusion of Product Innovations, *Economic Journal* **92**: pp. 630-653

Jovanovic, B. and S. Lach, 1989, Entry, Exit, and Diffusion with Learning by Doing, *American Economic Review* **79**: 690-699

Lieberman, M. B., 1984, The Learning Curve and Pricing in the Chemical Processing Industries, *Rand Journal of Economics* **15**: 213-228

Petrakis, E., E. Rasmusen and S. Roy, 1997, The Learning Curve in a Competitive Industry, *Rand Journal of Economics* **28** (2): 248-268

Spence, M., 1981, The Learning Curve and Competition, *Bell Journal of Economics* **12**: 49-70

Zimmerman, M., 1982, Learning Effects and the Commercialization of New Energy Technologies: the Case of Nuclear Power, *Rand Journal of Economics* **13**: 297-310

APPENDIX A:

We first consider the industry output X_t. Summing (7) for all i, we get

$$X_t = \phi(na - \sum_{j=1}^{n} c_{jt}) \tag{A1}$$

Rewrite (A1) as $\phi\sum_{j=1}^{n} c_{jt} = \phi na - X_t$ and substitute it into (7). By the definition of ϕ and σ, $\phi(1+n\sigma) = s/r$. We have

$$x_{it} = \sigma[\frac{a - c_{it}}{r} - X_t) \tag{A2}$$

Substituting (A2) into (19), we have firm i's cost in period t (t > 1)

$$c_{it} = (1+\frac{\alpha\sigma}{r})c_{it-1} - \frac{\alpha\sigma a}{r} + (\sigma\alpha-\beta)X_{t-1} \tag{A3}$$

Summing (9) for all i, we have

$$\sum_{j=1}^{n} c_{jt} = \sum_{j=1}^{n} c_{jt-1} - (\alpha+n\beta)X_{t-1} \tag{A4}$$

From (A1) we get

$$X_t - X_{t-1} = \phi(\sum_{j=1}^{n} c_{jt-1} - \sum_{j=1}^{n} c_{jt}) \tag{A5}$$

(A4) and (A5) imply $X_t = [1 + \phi(\alpha+n\beta)]X_{t-1}$. As $X_1 = \phi n(a-c)$, we solve the industry output in period t as

$$X_t = \phi n(a-c)[1 + \phi(\alpha+n\beta)]^{t-1} \tag{A6}$$

Substituting (A6) into (A3), we know that firm i's cost follows the difference equation

$$c_{it} = (1+\frac{\alpha\sigma}{r})c_{it-1} - \frac{\alpha\sigma a}{r} + (\sigma\alpha-\beta)\phi n(a-c)[1+\phi(\alpha+n\beta)]^{t-2} \tag{A7}$$

The unique solution of (A7) is (10). Plugging (10) and (A6) into (A2), we get (11).

APPENDIX B:

(i) If a increases and T remains unchanged, the left hand side of (16) rises more than the right hand side. To keep he two sides of (16) equal, T must fall. Then, the left hand side of (17) falls and the right hand side rises. Hence (17) is less likely to hold. The shakeout is less likely.

(ii) Suppose that β in (16) were equal to $\alpha\sigma$, then (16) became $(a-c_1)(1+\alpha\sigma/r)^{T-1} = a - \underline{c}$. When n increases, so does σ. As $(1+\alpha\sigma/r)^{T-1}$ must remain constant, T must fall. Now recall that true $\beta < \alpha\sigma$, so T actually does not need to fall so much. This means that $(1+\alpha\sigma/r)^{T-1}$ actually increases. To keep (16) valid, $[1+\phi(\alpha+n\beta)]^{T-1}$ must decrease. Therefore the ratio of these two rises when n increases. As $1 + \sigma n$ also rises in n, (17) is more likely to hold.

APPENDIX C:

(i) When α rises, if $\beta = \alpha\sigma$, (16) requires $(1+\alpha\sigma/r)^{T-1}$ to be constant and T must fall. As the true $\beta < \alpha\sigma$, T actually does not fall so much, hence $(1+\alpha\sigma/r)^{T-1}$ must rise as α increases. This implies that $[1+\phi(\alpha+n\beta)]^{T-1}$ must fall. Therefore the left hand side of (17) increases and the shakeout is more likely.

(ii) As β rises, the ratio $(1+\alpha\sigma/r)/[1+\phi(\alpha+n\beta)]$ decreases. Also, (16) implies that T decreases. So the left hand side of (17) falls and the inequality is less likely to hold.
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