This paper studies the monopolistic and perfect competitive market structures, where the production process incorporates learning by doing. This analysis provides conditions under which monopoly is preferred to perfect competition from the consumers' point of view.

1. Introduction

The purpose of this note is to study the effect of Learning by Doing (L.B.D.) on prices and quantity. In particular, we compare this effect in competitive market structure to that of monopoly structure. Traditional economic comparison of monopoly and perfect competition is based on a simple static analysis. Such analysis might be realistic and sufficient for several industries but cannot capture the intertemporal dependence structure that exist in many industries. An example for such intertemporal dependence and multiperiod comparison can be found in the economic theory of exhaustible resources. Thus a convenient way to discuss the learning economies is by pointing out the analogies and differences with the exhaustible resources results.

The basic result of this analysis is that since L.B.D. is related to the accumulated output of the individual firm, it affects the monopoly more than it affects competitive firm. Therefore, taking this dynamic aspect into consideration it is not so clear that competitive market is always preferred by consumers on monopoly. Any comparison between the two market structures must involve two elements. On the one hand, the monopolistic tendency to restrict output; on the other hand the stronger effect of learning on the

1By L.B.D. we refer to the phenomenon that unit production cost decline with accumulated output [see, for example, Arrow (1962) and Spence (1981)].
monopoly. If the learning effect is strong enough to overcome the regular monopolistic tendency to restrict output, the monopolistic output can be (at least temporarily) above the competitive output level.

2. Monopoly versus competitive industry

The exploitation of an exhaustible resource from a fixed reserve base has received considerable attention in the literature [see, for example, Pindyck (1978a, b) and Stiglitz (1976)]. One of the main questions in this literature was: to what degree will the price trajectories of monopoly and competitive market differ? It can be proved [see Stiglitz (1976, p. 656)] that under constant demand elasticity and zero extraction costs, the monopoly equilibrium and the competitive equilibrium are identical. However, if extraction costs are positive the monopolistic price is higher at the beginning and later will be lower than the competitive price. The extent to which the two price trajectories will differ depends on the production cost and on the particular way in which production cost increase as the resource reserve base is depleted.

Adopting Pindyck (1978a, p. 250) formulations of the monopolistic optimization problem, the monopoly has to choose an output path \( q(t) \) in order to maximize

\[
W = \int_0^\infty e^{-rt} [R(q(t)) - C(Q(t))q(t)] \, dt,
\]

subject to

\[
\dot{Q}(t) = q(t), \quad Q(0) = 0, \quad Q(t) \leq R_0,
\]

where \( R(q) \) is a revenue function, \( r \) is the discount factor and \( C(Q(t)) \) is the unit production cost which depends on the accumulated output.

Clearly this formulation of the exhaustible resources problem is similar to the monopolist learning by doing problem. While in the L.B.D. case \( C'(Q) < 0 \), Pindyck assumed that \( C'(Q) > 0 \) (another difference of course is that in the L.B.D. case the total accumulated output is unlimited). Solving problem (1), the optimal production path satisfies the conditions\(^2\)

\[
[MR(q) - C(Q)] e^{-rt} + \lambda(t) = 0,
\]

\[
\dot{\lambda} = dp/dt = r[MR(q) - C'(Q)].
\]

\(^2\)For more details, see Pindyck (1978a, p. 250).
While in the exhaustible resources case $MR(q) - C(Q) > 0$ and thus $\dot{p} > 0$, in the L.B.D. case $MR(q) - C(Q) < 0$ which implies that $\dot{p} < 0$. Moreover, from eq. (2) we see that the sign of the shadow price, $\lambda(t)$, will determine whether the monopolistic price will be lower or higher than the price charged by a myopic monopoly facing the same conditions. In the exhaustible resources case $\lambda(t) < 0$ and, therefore, the optimal price is above the short-run profit-maximizing price. In the L.B.D. case $\lambda(t) > 0$, and thus the optimal price is below the myopic monopolistic price. A similar result can be derived for the competitive market.

In the exhaustible resources discussion the comparison between monopoly and competitive industry is based on the assumption that the total quantity of the resource is given and fixed. As Stiglitz (1976, p. 656) pointed out, under this circumstance the monopolistic power is severely limited. The monopolist, like the competitive firms, will eventually exhaust all of the resource. Thus, the total extracted quantity, under both market structure, is fixed. In the L.B.D. case we deal with conventional commodity. The total quantity produced by the monopolist over time can be smaller than the competitive output and thus the monopolistic power is not limited.

Under the learning by doing assumption the necessary condition for the monopoly can also be written (using the transversality condition) as

$$MR(q(t)) - C_q(Q, q) - \int_t^\infty C_q(Q(\tau), q(\tau)) e^{-r(\tau-t)} d\tau = 0. \tag{4}$$

The general monopolistic maximization problem is

$$\max \int_0^\infty [R(q) - C(Q, q)] e^{-rt} dt \quad \text{subject to } \dot{Q} = q.$$

So forming the Hamiltonian

$$H = [R(q) - C(Q, q)] e^{-rt} + \lambda q,$$

we obtain the result that $q(t)$ must satisfy

$$[MR(q) - C_q(Q, q)] e^{-rt} + \lambda(t) = 0,$$

while

$$\lambda = e^{-rt} C_q(Q, q).$$

Therefore,

$$\lambda(t) = \int_0^t e^{-\tau t} C_q(Q, q) d\tau + \lambda(0).$$

Using the transversality condition $\lambda(\infty) = 0$ which is sufficient for $H \rightarrow 0$ as $t \rightarrow \infty$ yields

$$\lambda(t) = -\int_t^\infty e^{-\tau t} C_q(Q, q) d\tau,$$

and thus

$$MR(q) - MC(Q, q) - \int_t^\infty \frac{\partial C(Q, q)}{\partial Q} e^{-\tau t} d\tau = 0.$$
Similarly, the condition for the competitive firm is

$$p(t) - C_q(Q, q) - \int_t^\infty C_q(Q(\tau), q(\tau)) e^{-r(t-\tau)} d\tau = 0.$$  \hspace{1cm} (5)

The economic interpretation of this condition is that firms have to take into consideration the full marginal cost which consist from the direct marginal cost and the present value of all future additional profit due to further decrease of production cost. When we have a positive learning \( C_d(Q, q) < 0 \) the learning provides an incentive for firms to increase their output. In the presence of a negative learning [the exhaustible resources case \( C_d(Q, q) > 0 \)] there is an incentive for firms to reduce their production level. Thus for negative learning, the monopolistic power and the negative learning are in the same direction namely, to reduce the optimal output and to increase the price. Due to these incentives, in the presence of a positive L.B.D. the optimal monopolistic output level exceeds the output level of the myopic monopoly. (The same result holds for the competitive output.)

The extent to which the monopoly price and the competitive price differ, depends on the speed of learning in the two market structures, on the different incentives that monopoly and competitive firms have to increase their output and on the regular monopolistic tendency to reduce output.

Discussing the L.B.D. case we have to take into consideration that learning is a function of activity and experience. Thus the reduction in the unit production cost depends on the individual firm’s accumulated output. Comparing competitive market and monopoly we can argue that although the total market output in competition is usually higher than the monopolistic output, the output per firm in a competitive market is less than the monopolistic output. Consequently, the learning in the monopolistic market is faster and thus the reduction of production cost is faster. Moreover, using the usual limiting argument, one can see that when the competitive industry consists of a large number of firms it results in a very slow learning. Therefore, the monopoly will eventually have lower production cost which can result in a higher output than the competitive industry.

The same argument holds when we analyze the exhaustible resources case. Similar assumptions about negative learning yield that the increase in the monopolistic production cost over time is faster than in the competitive industry. Therefore, comparing the output level in the two market structure yields that, unlike the L.B.D. case, the negative learning and the monopolistic power are both in the same direction, encouraging the monopoly to reduce its output with respect to the competitive output.

Eqs. (4) and (5) also imply that beside the current marginal cost the firms take into consideration the future gains from learning (viz.
\[- \int_0^\infty (\partial C(Q,q)/\partial Q)e^{-r(t-t')}dt\]. This expression which describes the incentive that the non-myopic firms have to increase their output yields different incentives for monopoly and for competitive firms. Moreover these incentives are changed over time as the accumulated output and the optimal production level are changed. Using again the usual limiting argument we can say that it is possible to construct an example for which these incentives, that the L.B.D. provides for the competitive firm, can be as small as we want. [Assuming for example that \(C(Q,q)\) is bounded and \(r > 0\) then by increasing the number of firms and thus reducing the output per firm we can prove that the above incentive goes to zero.] Therefore we can conclude that under certain conditions, the third expression of (4) generates a greater incentive for the monopolist than the similar expression of (5) generates for the competitive firms.\(^4\)

Finally, traditional comparison between monopoly and perfect competition indicates that from the consumers point of view perfect competitive market is preferred. Discussing the exhaustible resources problem it was proved by Stiglitz that this result does not necessarily hold when there is a fixed stock of the natural resource. This result was based on the assumption that eventually the total quantity that the monopolist or the competitors will exploit is fixed. In this note we discuss the case of conventional good, for which the monopolistic power is not limited. However, when learning by doing exist the reduction of production cost over time is faster in a monopolistic industry. Moreover, the incentives that the monopoly has to increase its output in order to gain more experience might be stronger than those of competitive firms. Consequently, it is not obvious that under the L.B.D. assumption the competitive output trajectory is still preferred by consumers on the monopolistic output trajectory. Moreover, it is plausible that the monopolistic output will be greater, at least temporarily, than that of a competitive industry.\(^5\)

\(^4\)Another example is when \(C(Q,q) = C(Q)q\) and \(C'(Q)\) is constant (at least for every \(Q < \tilde{Q}\); such that \(\tilde{Q}\) can be interpreted as the accumulated level at which the learning stops to be effective). Under this assumption it is sufficient that the monopolistic output exceeds the output of an individual firm in a competitive market in order to prove that the third expression of (4) is bigger than the similar expression in (5).

\(^5\)In the limit when \(n \to \infty\) it can be proved that under general set of conditions the monopolistic output can be above the competitive output.

References


Pindyck, Robert S., 1978a, Gains to producers from the cartelization of exhaustible resources, Review of Economics and Statistics 60, no. 2.
Scherer, F. M., 1980, Industrial market structure and economic performance (Rand McNally, Chicago, IL).