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ENTRY AND LEARNING*

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the statistical or managerial modelling of the process of learning (e.g., Rapping 1965; Lieberman 1984; Joskow and Rozanski 1979; Summers and Welch 1970), or have examined the impact of learning on prices, industry structure, or strategic planning (e.g., Arrow 1961; Bhattacharya 1984; Haley 1979).[2] What is missing, as Baloff (1966) pointed out 20 years ago, is a theory of learning which integrates the descriptive cases and statistical results of the last 50 years:

> [It] appears that the generalization of this technique may have been hindered by the following deficiencies in the learning curve literature: (1) a narrow understanding of the causes, and hence existence, of the productivity phenomenon described by the learning curve; (2) some understanding as to the actual form or statement of the learning curve model; and (3) a lack of communication of past empirical results with the learning curve model (Baloff 1966, p. 275).

This lack of a theoretical structure[3] is at the heart of much of the recent criticism of learning curves. Abernathy and Wayne (1974) criticize many of the earlier applications of learning curves for fixation on cost, rather than profitability. This is reinforced by Porter (1980), who showed that firms using the experience curve concept had lower than expected profits. Day and Montgomery (1983) argue that model measurement, data, and theoretical issues have made most applications tedious, *ad hoc*, and very dependent on the nature of the application. Even Ghemawat (1985), in his defense of learning and experience curves, concedes that in past applications, researchers have been too willing to accept the existence of learning effects without adequate justification:

> To a strategist, the experience curve suggests that a company with the highest share of an industry's cumulated output will also be the low-cost producer, . . . [b]ut the Dupont and Ford examples show that such a strategy can be a recipe for failure. The experience curve is too complex to be encapsulated in simple prescriptions. Successful strategy formulation requires a closer analysis of how and why the curve works (Ghemawat 1985, p. 144).

In the most recent re-evaluation of the learning curve, Hall and Graham (1985) anticipate some of the criticisms to be highlighted in this paper. In their examination of past BCG and other statistical studies, they argue that many experience effects are spurious, confusing the impact of economies of scale, input factors price changes, and other technological improvements with learning.

Criticism of the learning curve is only a small part of a more general criticism which can be leveled at our understanding of the economic determinants and consequences of innovative activity. This is noted strongly by Nelson (1981, 1986) in his recent reappraisals of the economics of R & D.

> Contemporary orthodox theory of the behaviour of the firm and industry focuses mainly on the behaviour of firms operating with given technologies. In view of the history of Western economics, this is something of a puzzle. Much of Adam Smith's *The Wealth of Nations* is about what today would be called technical change and economic growth. These were the concerns of many of the great classical economists. It is not easy to understand exactly why micro-economic theory was purged of serious concern with long-run change (Nelson 1986, p. 460).

Theoretical deficiencies in our analysis of learning curves cannot be separated from our deficiencies in modelling the role and impact of R & D. Nor can we separate, as Gold (1981) notes, the phenomenon of learning from our general understanding of the determinants of cost and production by firms.

[2] Spence (1981), Rosen (1972), Hirshleifer (1965), Oi (1967), and Womer (1981), among others, have attempted theoretical integration of learning into an economic framework.

[3] By a 'lack of theoretical structure' it is not meant that the concept is not valuable as a descriptive model or intuitively correct in many circumstances. Rather it is meant that the model lacks integration into a more general theory of firm operations.

Much of the recent, and well justified, criticism of learning curves is rooted in the willingness of both managers and researchers to accept learning curve conceptions, without understanding that similar price and cost patterns may arise for reasons that have nothing at all to do with learning. A great deal of blame must be put on the simplistic univariate analysis of cost versus accumulated production found in many studies. However, the problem is an even deeper one. A learning curve is beneficial in that it provides the ability to examine the firm as a dynamically evolving entity in a competitive environment. However, a disproportionate number of theoretical studies on the impact of learning on firm decisions have used a monopoly market structure as their basis (e.g. Dolan and Jeuland 1981; Kalish 1981; Kalish and Lilien 1983).[4] Under these conditions the naive normative implications first set forth about the impact of learning on cost and price are validated. Unit price and cost fall with profitability rising over time. However, if entry and demand changes are permitted, it can be shown that almost any form of time path of cost and price may be consistent with learning.

The present paper highlights the difficulties in examining learning effects in the presence of entry and dynamic demand changes, using four separate cases. First, the simple dynamics of entry without learning are given. The time path of unit cost and price are shown to be identical to those attributed to learning. Building on this case, the cases of internal firm learning and industry learning are considered. Finally, the movements of cost and price over the product life cycle are examined. Each case uses a simple comparative static analysis to demonstrate the time paths of the relevant parameters. To conclude, the managerial implications of the current research are highlighted.

2. General Framework

Firms are viewed as discounted-value profit maximizers. Assume there are no barriers to entry (there are, however, fixed costs) and that firms will continue to enter sequentially so long as discounted profits are positive. Firms are assumed to be able to adjust capacity costlessly. Although on the surface this condition may appear restrictive, it really is not. It basically implies that there is no difference between the short-run and long-run cost curves of the firms.[5] It is further assumed that all firms possess U-shaped average cost curves. The individual firm's optimization problem is to maximize discounted profits by altering quantity.[6]

$$\underset{q_i(t)}{\text{MAX}} \sum_{i=O_i}^{\infty} \Pi_i(t)/(1+r)^{i-1}, \qquad \text{where} \tag{1}$$

$$\Pi_i(t) = P[Q(t)]q_i(t) - C\left[q_i(t), \frac{q_i^*(t)}{q_i(O_i)}, \frac{Q^*(t)}{Q(O_1)}\right] \qquad \text{with} \tag{2}$$

$\Pi_i(t)$ = profits of firm i at time t;
$q_i(t)$ = quantity produced by firm i at time t;

[4] The primary reason for the formulations used in these studies appears to be the mathematical tractability of the monopoly model. Even Wernerfelt (1985) restricted his analysis of the product life cycle to that of a duopoly.

[5] This is an important point and one that has never, to this author's knowledge, been brought up in learning curve studies, although it is recognized as a source of confusion by economists concerned with the estimation of economies of scale and technological innovation (Gold 1981; Nelson 1981). Over time firms will be moving from one short-run cost curve to another as they adjust capacity to changing circumstances. Whether or not this should be called learning will be discussed in §6. However, this issue will considerably complicate, to no good purpose, the upcoming analysis and will be ignored.

[6] Only one-characteristic commodities are being analyzed. Quantity, therefore, fully determines price.