

Competitive Cost Dynamics: The Experience Curve

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This is the first of three articles about some popular tools that have been widely used since the early 1970's to support strategic decision-making. The article below deals with the experience curve; subsequent articles will deal with the growth-share matrix and the industry attractiveness-business strength matrix. These tools have inspired a degree of controversy about their uses and limitations, issues that will be explored in this and the subsequent articles.

This is the first of the tutorial articles we will be publishing in *Interfaces*. The objective of a tutorial article is to describe an important technique or an application area for *Interfaces* readers who are nonexperts in the field. Please write and let me know what area(s) you would like to see covered in tutorial articles (and who you would like to see write them) and what area(s) you would be prepared to cover in a tutorial of your own.

Gary L. Lilien

This, the first of our series of three tutorial articles, explains the use of

the experience curve for understanding the cost dynamics of an industry and po-

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sitioning a firm strategically within that industry.

The management of cost of manufactured products is fundamental to long-term profitability for any firm operating in a competitive market. To a great extent, the strength of a business rests on its ability to deliver products at costs lower than its competitors. The cost of a product should not be viewed as the simple accumulation of direct and allocated expenses for its manufacture and sale, but also as an indicator of the firm's ability to manage its resources.

The experience curve is a key tool to assist managers in formally addressing the question of the competitive cost structure. It provides an empirical relationship between changes in direct manufacturing cost and the accumulated volume of production. Although its origins go back to the beginning of this century, it was only in the late 1960's that the Boston Consulting Group began to emphasize the ex-

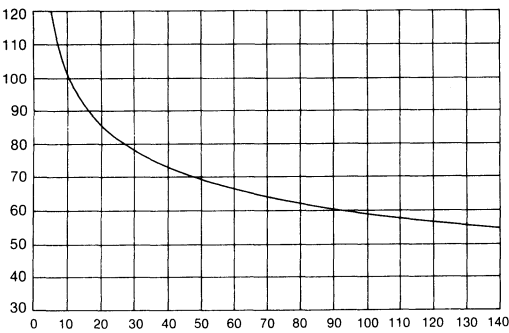


Figure 1. An 85% experience curve. The horizontal axis is the accumulated volume of production (in units), and the vertical axis the deflated direct cost per unit (the actual cost corrected for inflation). Every time the accumulated volume of production doubles, the cost per unit decreases to 85% of the previous level.

perience curve's role for strategic decision making [1972].

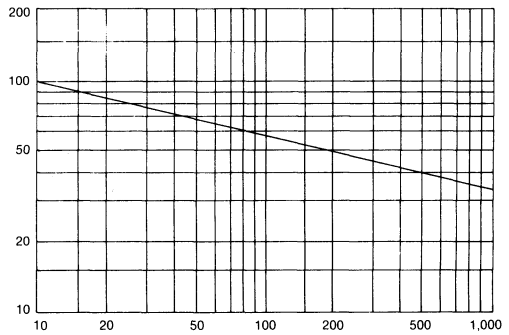


Figure 2. The relationship between the accumulated volume of production (horizontal axis) and the deflated direct cost (vertical axis) expressed in a log-log graph as a straight line, again, an 85% experience curve.

The experience curve shows that the cost of doing a repetitive task decreases by a fixed percentage each time the total accumulated volume of production (in units) doubles (Figure 1). For example, the total cost might drop from 100 when the total production was 10 units, to 85 (= 100×0.85) when it increased to 20 units, and to 72.25 (= 85×0.85) when it reached 40 units. This relationship between the accumulated volume of production and the deflated direct cost can be expressed in a log-log graph as a straight line, which is easier to work with (Figure 2). It should be emphasized that the accumulated volume of production represents the total number of units delivered since the very beginning of the production activity, and it should not be confused with the production rate, which corresponds to the number of units delivered in a stated period.

If nominal rather than deflated cost were to be used in plotting the experience

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curve, none of the previous effects could be observed. Most likely, instead of a decreasing cost curve, we would have obtained an increasing and unsystematic cost pattern.

The cost predicted by the experience curve effect can be obtained from a simple negative exponential relationship of the following type:

$$C_t = C_0 \left(\frac{P_t}{P_0} \right)^{-a}$$

where:

C_0, C_t = cost per unit (corrected for inflation) at times 0 and t , respectively;

P_0, P_t = accumulated volume of production at times 0 and t , respectively;

a = constant, which reflects the elasticity of unit costs to accumulated volume.

In the 85% curve, the constant "a" can be obtained by recognizing that doubling the production reduces the cost to 85% of its initial value. This corresponds to introducing the values

$$C_t/C_0 = 0.85 \text{ and } P_t/P_0 = 2$$

in the expression: $\frac{C_t}{C_0} = \left(\frac{P_t}{P_0} \right)^{-a}$

The resulting solution is $a = 0.234$.

Other values of this constant for different slopes of the experience curve can be figured (Figure 3). The reduction that may be obtained by the experience effect is dependent on the industry. For example, the manufacturing of integrated circuits approaches a 70% slope, air conditioners show an 80% slope, and primary magnesium exhibits a 90% slope. Similar observations are obtained from other indus-

tries like cement manufacturing (70% slope), power tools (80% slope), and industrial trucks (90% slope).

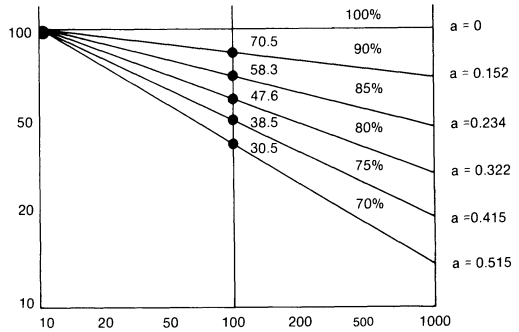


Figure 3. Experience curves for different relationships between accumulated production and deflated unit cost. For example, the 80% experience curve shows that the unit cost is reduced from 100 to 47.6 after a ten-fold increase in accumulated volume of production. The entire straight line corresponds to the negative exponential relationship

$$C_t = C_0 \left(\frac{P_t}{P_0} \right)^{-a}$$

the constant a being 0.322 in this case.

The actual significance of the experience effects for a given industry depends not only on its inherent slope, but also on the speed at which experience accumulates, measured by the rate of growth in the market (Table 1).

The potential for cost reduction is greatest in industries with strong experience effects and fast growing markets, like the semi-conductor and computer industries in recent years.

Managing the Experience Effect to Reduce Cost

Although the impact of experience on lowering costs has been measured empirically in a wide spectrum of industries — ranging from broiler chickens to integrated circuits — its benefits can only be

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Experience Curve Slope	Annual Market-Growth Rate				
	2%	5%	10%	20%	30%
90%	0.3	0.7	1.4	2.7	3.9
80%	0.6	1.6	3.0	5.7	8.1
70%	1.0	2.5	4.8	9.0	12.6
60%	1.4	3.5	6.8	12.6	17.6

Table 1. An estimate of the percentage of annual cost reductions for different combinations of experience-curve slope and annual market-growth rate. The potential of cost reduction is greatest in industries with strong experience effects and fast growing markets.

realized by careful management. The effects of the experience curve can be observed in every stage of the value-added chain. It affects each one of the value-added steps: research and development, procurement of raw materials, fabrication, assembly, marketing, sales, and distribution. The most important factors for a systematic decrease in cost with accumulated volume are:

(a) *Learning*. In repeating a task over and over, a person develops skills which allow him to do the work more efficiently. For this reason, the productivity per worker is expected to rise with increased dexterity [Hirschmann 1964].

(b) *Specialization and Redesign of Labor Tasks*. The increased volume leads to a division of labor that allows for specialization and standardization both contributing to improved productivity.

(c) *Product and Process Improvements*. As volume increases, many opportunities open up to improve the product and process and thereby achieve higher productivity and cost reductions. The kinds of changes that generate increases in productivity are modifications in the product, better utilization and substitution of materials, and rationalization of the product-

mix; all of them dictated by the increased experience resulting from larger volume. Added opportunities for cost reduction arise from changes in the manufacturing process. Improved technologies, layout changes, better ways of handling and storing materials, parts, and products, adoption of more efficient maintenance methods, and better distribution of final products are some of the alternatives that can drive costs down. In general, the idea is to look for all improvements that can reduce costs.

(d) *Methods and Systems Rationalization*. Opportunities increase for improving the performance of a firm by introducing more up-to-date technology for handling operation. Also, adopting a policy of standardization allows coordination of different activities in the various steps of the value-added chain.

(e) *Economies of Scale*. The cost reduction observed in a historical series of real costs can be partly explained by the impact of accumulated volume of production and partly by the changes of scale from increased throughput. The economies of scale correspond to the decline in unit costs as throughput increases. Economies of scale can affect nearly every function, and many technological factors combine to produce the downward trend of the cost-curve as volume increases. The dominant factors are:

- Improved technological processes for high volume production;
- The resources that can be profitably used together only in large operations;
- The possibility of integrating manufacturing processes for the various business activities of very large firms

operating in stable environments;
 — The sharing of resources, mainly those managed at the corporate level, that is possible for diversified firms with businesses in related product markets.

A typical scale effect can be seen in the use of the “.6 — .8 rule” for estimating the investment required for a given plant capacity. The rule, which applies in many industrial settings, is that if capacity is doubled, the investment required increases only 2ⁿ with the exponent varying between .6 and .8. This corresponds to an increase between 52% and 74% of investments for a 100% increase in capacity. Similarly, scale effects can be observed in distribution, sales, research and development, general administrative activities, and all stages of production.

Cost reductions with increased scale are another way for managers to improve their competitive cost position. When these factors are properly managed they can reduce the total cost of a product.

(f) *Organizational “tune-up.”* A subtle result of experience is the “tune-up” achieved by the organization after a long history of production, which is reflected in technological know-how and well developed formal systems that provide guidelines for smooth relationships among individuals responsible for different tasks in the production process. This organization tune-up is an asset that should be fostered and protected because it can give a competitive edge to a firm.

Strategic Implications: the Value of Market Share

Because a decline in unit costs accompanies an increase in production, market

share is a primary variable in the strength of the strategic position of a business within an industry. Among those who advocate this view is the Boston Consulting Group, who state the following chain of causal relationships: high market share causes high accumulated volume of production causes low unit cost causes high profits. The association between market share and profitability has received empirical support in the work of project PIMS (Profitability Impact on Marketing Strategies) [Schaffler, Buzzel, and Heany 1974; Buzzel, Gale, and Sultan 1975].

The implications of these relationships are clear when competing firms are positioned within a common experience curve; the firm with the largest volume has a commanding advantage over its competitors. The firm with the lowest volume struggles for its survival at the mercy of the strategic moves of the top firm and its own ability to sustain long-term losses (Figure 4). Under this approach, the only way for the low firm to improve its situation is to aggressively search for an increase in market share.

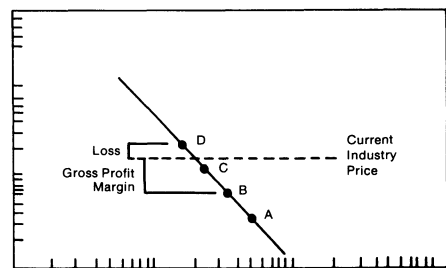


Figure 4. Four firms, A, B, C, and D positioned on a common experience curve clearly showing the advantage of large volume. Again the vertical axis is deflated cost per unit and the horizontal, accumulated volume of production.

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Bruce Henderson, the founder of the Boston Consulting Group, has been a leading spokesman for this approach. In this book *On Corporate Strategy* [1979] he proposes the "rule of three and four," which says that:

A stable competitive market never has more than three significant competitors, the largest of which has no more than four times the market share of the smallest.

There are two primary reasons argued by Henderson to sustain this hypothesis:

A ratio of two to one in market share between any two competitors seems to be the equilibrium point in which it is neither practical nor advantageous for either competitor to increase or decrease share.

Any competitor with less than one quarter the share of the largest competitor cannot be an effective competitor.

The most important strategic implications suggested by Henderson are:

If there are a large number of competitors, a shakeout is nearly inevitable in the absence of some external constraint or control on competition.

All competitors wishing to survive will have to grow faster than the market in order to maintain their relative market shares with fewer competitors. The eventual losers will have increasingly large negative cash flows if they try to grow at all.

All except the two largest share competitors either will be losers, and eventually be eliminated, or will be marginal cash traps reporting profits periodically and reinvesting forever.

The quicker an investment is cashed out or a market position second only to the leader is gained, then the lower the risk and the higher the probable return on investment.

Definition of the relevant market and its boundaries becomes a major strategy evaluation.

The validity of the rule of three and four is arguable. It is presented to illus-

trate the way a set of normative implications have been derived by interpreting the effects of the experience curve. What seems to be true is that industry concentration tends to be very high under stable conditions, and where this is not observed, perhaps the appropriate market is not defined correctly, or government regulations prevent the natural course of adjustments.

The Price-Cost Relationship

Although cost has a fairly predictable trend along the experience curve, prices do not. Early in the introduction of a new product, the innovating firm makes a strategic decision about price. The major question is whether to set a high price in the initial phases, when it is possible for the innovator to impose a monopolistic rent and enjoy an extraordinarily high profit, or to lower the prices at the same rate at which costs decline to discourage the entry of competing firms into the business. Usually in the introductory and embryonic stages prices tend to be fairly stable, providing a real bonanza for the innovative firm (Figure 5). This has been the case for electronic watches, video recorders, hand electronic calculators, and similar technology-intensive consumer products. As the embryonic phase ends, the entry of new competitors generates a turbulent shakeout in the industry with a rate of price reductions much faster than the cost decline. Quite often, a complete restructuring of the industry takes place at this stage, and even the original innovator may be forced out of business. That happened to Bowmar in electronic hand calculators.

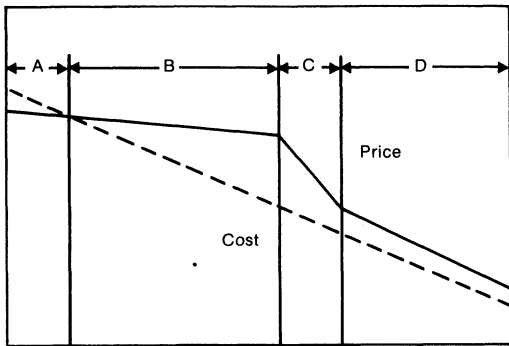


Figure 5. The relationship of price and cost (vertical axis) during the different stages in the life cycle of a product. Introduction (A), embryonic stage (B), shakeout period (C), and maturity (D), with the horizontal axis representing accumulated production.

At the end of the shakeout phase, only a few of the most efficient producers survive, and despite their small number, the profit margin should be consistent with a perfect market situation throughout the maturity stage of the product.

Using the Experience Curve in Strategic Planning

The experience curve provides important insights for strategic planning, particularly in high-technology firms. However, according to Strategic Planning Associates, Inc., its use depends on some subtle guidelines. Not recognizing these guidelines can lead to misuse of the experience curve.

To determine the chronology of the experience curve, the starting point for the accumulation of experience must be detected. Also, occasionally, shifts in the experience curve take place over a long time span (Figure 6). Using an average slope will grossly underestimate the effects of recent technological advances or

capacity expansions after major capital investments.

Assessing the Starting Position of a New Entrant

The strategic implications discussed so far require a common experience curve for every competitor in an industry. This assumption can be violated in two different situations.

First, a new entrant can support its business on a technology whose experience curve behaves differently (Figure 7). In spite of the larger accumulated volume of the established top firm compared to the new entrant, it may not have a cost advantage because of the different patterns of the two experience curves. The dominance of the Japanese in the US steel industry might be explained in this way.

A second way to explain an improved position of a new entrant, other than technological differences, is the quick transfer of technology and know-how as a

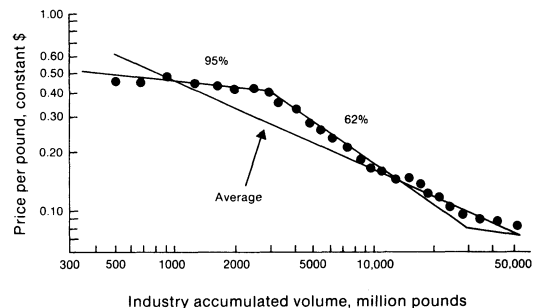


Figure 6. The accumulation of experience for Polyvinyl Chloride shifted from a 95% curve to a 63% curve after 2000 million pounds had been produced by the industry. Using an average slope would grossly underestimate the effects of recent technological advances or capacity expansions. [Source: Henderson and Zakon 1980]

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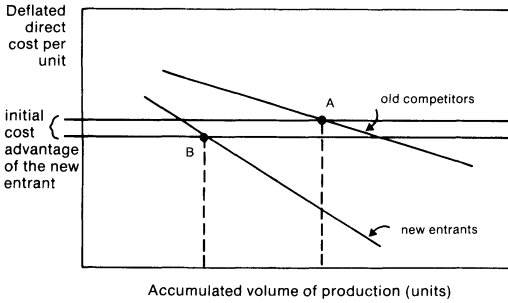


Figure 7. The experience curve of a new entrant whose business is supported by technology with a different experience curve than its competitors.

new entrant follows the lead of the established firm. In today's industrial world of fast communications, it is often impossible to retain proprietorship of process and product technology. A new entrant with an experience curve of identical slope to that of the leader will have a better initial position than would have been predicted if no technological transfer had taken place (Figure 8).

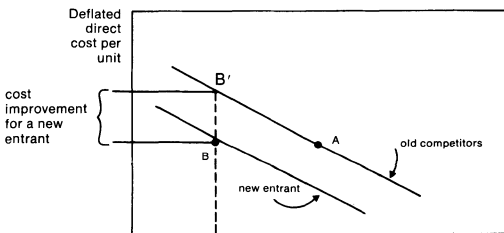


Figure 8. The experience curve of a new entrant with smart followership and transfer of technology. The unit cost for a new entrant B is identical to that of an old firm A, despite the large difference in accumulated volume of production (horizontal axis), because of the quick transfer of technology and know-how as the new entrant follows the lead of the established firm. Without this transfer of technology, new firms would follow the experience curve of old competitors, and the unit cost for the new entrant would be at the level B' instead of B.

Market Share is Not the Only Game

There are some industries in which experience does not seem to play much part in cost reduction. In those industries, the strategic position of a business does not rely on cost advantages. This is the case with producers of specialty products. Commodity products have few opportunities for differentiation that can induce the consumer to pay a price premium. Specialty products, on the other hand, offer distinctive features valued by the consumer. The closer a product is to a commodity, the more its cost becomes crucial.

The classic example of this is Ford's loss of leadership in the automobile industry. In spite of the fact that Ford reduced its costs by 15% from 1908 to 1925 [Abernathy and Wayne 1974], it was overtaken by General Motors because of their creative strategy of segmentation of the market under the slogan "A car for every purse and every purpose." Ford was wrongly treating a car as a commodity ("I will give you any car provided it is a model T and it is black."), without realizing that the American public was ready to pay a price premium for a more distinctive product.

Don't Measure Only at the End of the Value-Added Chain

A productive activity is composed of many different steps that can be ordered by stages of value-added. Among these stages are research and development, manufacture of parts, assembly, marketing, distribution, and retailing. Although experience will affect all these stages, seldom will it affect all of them equally, for

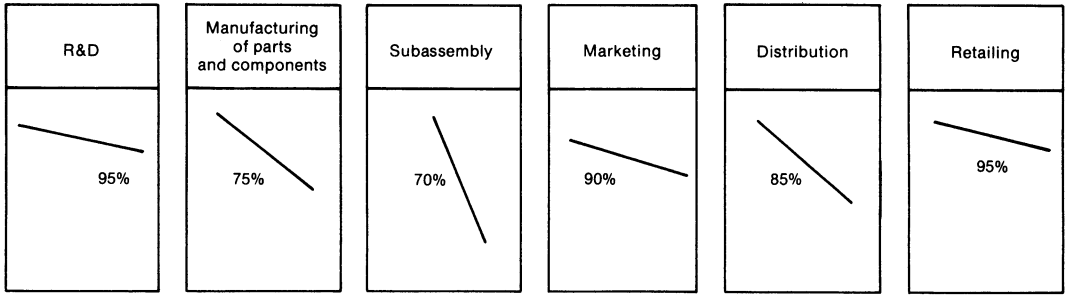


Figure 9: The effect of accumulated experience on the cost accrued in different stages of value-added. In this example, the productive activity is composed of six stages of value-added: research and development, manufacture of parts, assembly, marketing, distribution, and retailing. Experience is accumulated at different rates in each stage, represented by the slopes of the lines. For instance, the 95% slope for retailing indicates that experience in retailing is not as important as it is in assembly with a 70% slope.

instance, the 95% slope in retailing compared with the 70% slope in assembly indicates that experience in retailing is not as important as in assembly (Figure 9).

In addition to the different effects of experience because of the nature of the work, the impact of product mixes contributes to the accumulation of different amounts of experience at each stage. This situation is observed in firms manufacturing many products that load with a different emphasis the various stages of the value-added chain. Experience will accrue more rapidly to those stages which are heavily loaded by the entire set of items produced.

Both of these effects must be recognized, and market share should not be measured just at the end of the productive chain.

To illustrate, in a business, the leader of the market is firm A with a market share four times that held by its competition, firm B. At first, it looks as if firm A has an insurmountable advantage, but this impression is tempered when the business is conceptualized in terms of two stages of

value-added: manufacturing and distribution. In the manufacturing stage, firm A has a four to one advantage over firm B, but in the distribution stage, it is firm B which has an advantage of three to one because this business shares a system of distribution with many others. Assuming that experience in both stages has the same impact over cost, and that each stage contributes half the final value of the product, we could use a normalized market share to determine the relative standing of the two firms in the business.

$$\begin{aligned}
 &= (4 \text{ to } 1 \text{ or } 4/5) (0.5) + (1 \text{ to } 3 \text{ or } 1/4) \\
 &\quad (0.5) \\
 &= 0.525
 \end{aligned}$$

Similarly, for firm B we obtain a market share of 0.475.

The relative market share of firm A over firm B in this weighted measure of experience is only $0.525/0.475 = 1.10$ times, which is far smaller than the four to one obtained by considering only the final product.

Beware Overemphasizing Experience

Too much reliance on increasing scale and driving down costs might have unde-

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sirable effects. Too much emphasis on economies of scale might impair the firm's ability to respond to technological advance, environmental changes, and innovations taking place outside the firm. Also, it could prevent the firm's diversifying its products to capture a wider range of customers.

A successful firm might find itself chained to its existing business base, and prevented from adapting for long term and sustained profits. Success could be your worst enemy.

Diagnosis of the Industry Cost Structure

An assessment of the industry cost structure depends on determining the experience curve for each competitor in the industry. Where a single experience curve is common to everybody, the market share of each competitor is crucial to assessing their strength. When this is not the case, identifying the stages of value-added and the different technologies in use can provide insights for the strategic positioning of a business in that industry.

This might explain highly successful strategies such as the entry of Phillip Morris into the beer industry with Miller Light. Normally, entry into an aging industry is regarded as a highly unnatural and unproductive strategy. However, the success of Phillip Morris was based on a coherent set of strategies which included: heavy investment in new and efficient production facilities; introduction of an innovative product with a high potential market; and impressive marketing and distribution. This approach put Phillip Morris in a completely different experience curve than its competitors.

The entry of Procter and Gamble into the paper towel business against Scott Paper demonstrates the usefulness of identifying market share by stages of value-added. If market share, and therefore accumulated experience, were measured only by products sold, one would imagine that Procter and Gamble could do nothing in that business. However, the dominance of Procter and Gamble in marketing and distribution allowed them to start with a much stronger position than would otherwise be anticipated. It is this kind of strategic position that has permitted Procter and Gamble to enter late in many other consumer-product markets, without apparently having much of a disadvantage in its cost structure.

Projecting the Cost Structure

Very often firms in high technology areas, where experience plays a fundamental role, bid for contracts which, if obtained, would move them to the right of the experience curve and lower the cost of the units produced. It is essential to forecast such cost reductions so that the bids will incorporate them.

If the bid were to be accepted, the firm would need to use those projections, which were the basis for cost estimates, as controls. The actual cost realized would then be plotted in the experience curve charts against the estimates to detect any deviation. Management could then correct problems causing low productivity.

Events similar to those described took place in the aircraft division of a major firm. This firm simultaneously won bids from three government agencies. The combination pushed its production up by

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one order of magnitude. The bid cost per unit had been computed, passing the assumed cost reductions along to the client. Strict control of actual cost in each stage of production was necessary to make sure that the contracts would be profitable for the firm.

The Selection of a Generic Strategy

Michael Porter [1980] advocates three generic strategies to help a firm identify the position of a given business. The first strategy aims at *cost leadership* which depends on the firm having lower costs than its competitors. This strategy fully exploits experience curve effects.

The second generic strategy seeks for *differentiation*. Here the firm attempts to develop distinctive products in a given business to provide an advantage over the firm's competitors.

The third generic strategy consists of *targeting* a particular market segment where the firm can develop a distinctive strength.

Each strategy is designed to secure a long-term sustainable advantage in a competitive market, and each attempts to pursue that goal in quite distinct ways. The justification for this positioning can be understood after recognizing the U-shape effect that is observed in the behavior of profitability of firms competing in some industrial sectors (Figure 10).

Firms with either large or small market share can get a high return on investment, while firms in an intermediate situation will have a depressed profitability. In fact, if a firm achieves a level of sales allowing the exploitation of the full ben-

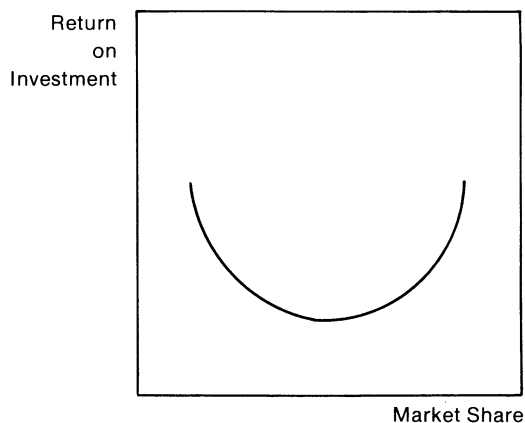


Figure 10. Firms with either large or small market share can get a high return on investment, while firms in an intermediate situation will have a depressed profitability. A large market share allows the exploitation of the full benefits of the experience curve, thus leading to high profitability. Small market share can only be viable in the long run with either a special product focused to a particular market or a unique item clearly differentiated from the competitors products. In both cases the firm can enjoy a price-premium also leading to high profitability. The worst situation is in the lower part of the U-curve with no cost advantage and no distinctive product to offer.

efits of the experience curve (a large market share), strategies that lead to cost leadership can truly pay off. If the firm cannot achieve a high level of sales, two alternatives are open. One is to choose unique differentiation, so the firm can enjoy a price-premium because of the special character of its products. The other is to redesign to target the output of the firm to a particular market. In both cases a small market share and a high profitability are obtained.

The worst situation is in the lower end of the U-curve with no cost advantage and no distinctive value to offer.

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Conclusion

Although we have discussed the strategic implications of experience effects, it will not be a surprise to experienced managers that there are no simple answers to complex problems. The experience curve with its implicit message that benefits can be obtained by increasing the volume of production is valid and relevant. However, a blind and narrow pursuit of cost reductions by simply accumulating experience could lead to an unexpectedly poor position in the market place. Despite the series of warnings presented to make the best of the lessons of experience, the important message of the experience-curve methodology is that cost can and should be managed if firms want to insure a solid position in the market-place.

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