#10

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Costs and Production

Preview

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THIS chapter explains some quantitative relationships between costs and outputs. Students who take only one course in economics will not find this chapter as valuable as will those who plan to take economics as a major field of study. To accommodate the first group of students, we present at the outset what should be an adequate summary statement of the main propositions. Those who plan to be economics majors will want to read the chapter with care; for them the brief summary at the beginning should serve as a helpful guide to the chapter: (1) The behavior of cost already enunciated and explained in the preceding chapters related costs of production to the speed or rate at which the product was produced. The higher the rate of production the greater the average and the marginal costs. (2) Now we present a second proposition that most people are already familiar with in everyday experience: the greater the volume to be produced, the lower the average and marginal costs, at any given speed of production—known as the law of the economies of mass production. For example, if ten automobiles of a given model are to be produced, each will cost more than if 100,000 of that model are made. Custom-made items are more costly than mass-produced items of the same quality. (It is this second law that some students have in mind when balking at acceptance of the first law in earlier chapters.) But the two entirely different propositions are consistent with each other. (3) When different output programs are compared in a special way, we get another proposition. We compare output programs, *all* lasting one year, but differing in their rates and volumes as follows. If the output *rate* is twice as large, the total volume produced in the year is also doubled. The total time-length of the production run is not changed—just the *rate* of production, and with it necessarily the total volume produced. If the rate is increased for a given interval of time, the volume produced in that interval will increase in the same proportion. If we compare the costs of this series of alternative potential output programs, all starting at any given moment and lasting the same length of time, average cost per unit can fall with increasing output at the smaller scales, but as one moves to the very high rate-volume programs the average cost of output rises. Why is there this U-shaped relation between average cost and size of output program? The fact is that the volume effect in reducing average costs loses force at very large volumes, whereas the cost increasing effect of higher *rates* gets stronger at the very high rates. So if potential output programs are arranged according to the scale of the output program, where the scale is measured in terms of *both* (i) the speed (or rate) of production and (ii) the total volume to be produced in the given interval, we get average cost (and marginal) curves like that shown in Figure 15–3.

That summarizes the main cost-output relationships. The chapter explains them with specific numerical examples and graphs in order to make the propositions more familiar and easier to use. In the course of the discussion a few other related ideas are explained. We indicate different stages in a production program and the ways the costs of each can be measured; the meanings of short-run and long-run output programs; joint production; and depreciation, obsolescence, and replacement of equipment.

To avoid getting bogged down in a variety of costs that can be confusing, we suggest that you not try to retain each one in mind as you proceed. Instead, look for the meaning of each action and see how its cost is computed. Only a few will be used in our subsequent analysis, but they can be more precisely understood later if the variants are initially distinguished. Read pages 257, 258 to see how costs are computed for some steps in an output program. Then in pages 259–265 we shall see how costs depend on the size or dimensions of an output program.

Costs of Acquisition, Continuing Possession, and Operation

Normally, we speak of the purchase price as the cost—when the resale price is typically zero, as for bread, shoes, or socks. But for many long-lived capital goods, the resale price is far from zero. With an ordinary new car, it may be 85 to 90 percent of the initial purchase price. If you buy a car for $2,000 and then immediately resell it for $2,000, the cost was zero. If you had resold it for $1,800, the cost you incurred would have been $200. The longer you keep possession of the car, the less will be the resale value. That subsequent depreciation in resale value is the cost of *continuing* possession, whereas the initial, immediate turn-around, purchase-resale price differential is a cost of *acquisition.* To make the example concrete, suppose the initial purchase price is $2,000, with an immediate resale value of $1,800, and with a subsequent $1-a-day depreciation in resale value. (1) The acquisition cost is $200, the difference between price and current resale value. (2) The cost of continuing possession of the car is $1 per day. The cost of *acquiring* ownership of a car and *keeping* it for one week is $207.[1] (3) The cost of driving it 1,000 miles in a week, assuming the operation costs are 6 cents a mile, is $60. The total costs thereby incurred are $60 for the gasoline, $7 for the depreciation—a total of $67 for *operating and continuing possession* of the car. On the other hand, if I do not yet have the car, the total cost of *acquiring, continuing possession, and operating it for one week* would be $267.

[1] The cost of keeping it for another week—*given* that I have already acquired it—is $7.

Fixed and variable costs. You might think these costs would normally be called (1) acquisition (or entry) cost, (2) continued possession cost, and (3) operating cost. But conventionally they have been called almost everything except those names. Sometimes, (1) is called "fixed" (or "sunk") cost, to suggest that once you acquire the item this cost is "fixed" upon you and irrevocable. For *any subsequent* decision this "cost" is totally irrelevant and can be forgotten. When "fixed" is applied to this first cost, the term "variable" is applied to the *sum* of (2) and (3) costs, in the sense that you could vary them by *shutting down and selling out* or varying the output plan.[2] (3) is called out-of-pocket costs.

Before we go to a detailed explanation of why the preceding distinctions are made, and how costs depend upon output, a few subsidiary points should be noted. First, do not confuse all expenditure with cost. Expenditure may be an exchange of one form of wealth for another—usually money for nonmoney goods. *Cost* of an *action* is the associated *reduction* in *total wealth*. Second, a cost of $200 *incurred now* by some action does not mean that one must reduce his *consumption* now. He may continue to consume at the same rate, deferring the reduced consumption till later. And there is nothing wrong or irrational with deferring the consumption sacrifice. Many young people do this by buying on installment plans. Third, to incur a cost does not mean one is worse off. When you buy the car and lose, say $200 in wealth, it means only that you could not now go back (by a market exchange) to your original set of resources. But if you knew that the cost of acquiring the car was going to be $200 (difference between the purchase and the immediate resale price) we presume you decided that having the car was worth that cost, and also worth the sacrifice of other services you could have had instead.

Per-Unit-of-Service Measures of Costs

Costs can be expressed per units of output, in particular as costs per mile of service. For example, for a two-year, 20,000 mile program, which we assumed in the preceding chapter, we simply divide the total costs by 20,000 miles to get the average (per mile) cost. The results are in the extreme right column of Table 15–1: $1,678.90/20,000 = $.084, a little more than 8 cents per mile. You can cover that cost with revenue if you rent your car for 8.4 cents per mile—but you must *collect the receipts in advance*. If you wait until the mileage occurs, interest should be included, since the measure used for cost is a *present*-value measure. If you were to be paid by credit-card at the end of each year, how much should you demand from the renter of the car? Or, what uniform two-year annuity (payments at the end of a first year and a second year) will have a present value of $1,678.90? Using Table 11–3, we get (at 10 percent) $969, due at the end of each of the two years (9.69 cents per mile paid when transport service is provided).[3]

The average *present* value cost of 8.4 cents per mile can be partitioned into operating (variable) costs and a remainder (which does not depend upon the mileage) here called the "possession" or "fixed" cost. $644.40/20,000 = 3.2 cents per mile, the per-mile

[2] Just to confuse things, apparently, economists use the expression "fixed" cost to refer to the first two costs, with "variable" for just the third one.

[3] Since the receipts are to be spread over a two-year period, with interest at 10 percent each year, the payment due at time of mileage is delayed on the average about 1.5 years. At 10 percent per year, that is about 15 percent interest per 1.5 years. As expected, 9.69 cents is about 15 percent larger than 8.4 cents. Hereafter, to simplify computations, we shall express all costs, whether for the total program or a unit of mileage basis, in terms of the present-value measure.

TABLE 15–1. Total Cost (Present Capital Value) Dependence on Volume (Miles of Service) at *Constant* Rate of 10,000 Miles per Year

Distance (Miles)	Total Cost	Incremental Cost	Average Cost
5,000	$ 750	$750	$.150
10,000	1,100	350	.110
15,000	1,400	300	.093
20,000	1,679	279	.084
25,000	1,940	261	.078
30,000	2,200	260	.074
35,000	2,420	220	.067
40,000	2,600	180	.065
45,000	2,760	160	.061
50,000	2,900	140	.058

average *direct operating*, or variable, costs—excluding the initial acquisition *and* subsequent continued possession costs. The per-mile "fixed" possession cost is ($1,678.90 − $644.40)/20,000 or 5.2 cents. (Remember, this is merely the fixed cost spread over the 20,000 miles. The greater the mileage provided in those two years, the lower will be the per-mile average measure of that "fixed" cost.)

Let us compute one more average cost. What is the cost of the program minus *only* the ($200) initial acquisition cost? If the *already acquired* car is kept and used for 20,000 miles in two years, $1,478.90 in costs will be incurred. On a per-mile basis over 20,000 miles that is 7.4 cents per mile, excluding only the initial acquisition cost. This is
5, 6 an "average variable" or avoidable (if operations ceased) cost.

"Size" of Output Programs

There are several dimensions of "size" of an output program. One is the *volume*, or amount, of the good to be produced. A second is the *rate*, or speed, at which that volume is produced once it is under way. Finally, there are the *dates* of the output (for example, dates it is to be started and completed). In making refrigerators, the manufacturer can plan a volume of 150,000 refrigerators at the rate of 15,000 per month (for ten months), with the first completed item to appear six months from the date of decision to produce. The *volume* is 150,000 items, the *rate* is 15,000 per month, and the *date* is six to sixteen months hence. In the rest of this chapter, we will discuss how these three components of "size" affect cost.

Cost Effect of Volume

A larger volume (mileage or distance, in our current example) for some given initial date and constant rate of output will cost more than a smaller volume. More resources are required. In our automobile example, mileage is the volume. If mileage is to be 40,000 miles in *four* years rather than 20,000 in two years (constant *rate* of 10,000 miles per year), the total cost will be greater. But although the volume (40,000 miles) is twice as large, the total cost will not necessarily be doubled. *Generally the cost increase will be less than in proportion to the increase in the volume* (keeping the *rate* unchanged). The average cost per mile falls as the volume (mileage) increases. This is an economy of large or "mass" production.

The *volume* effect is important in reducing average and marginal cost for mass-produced, large-volume-of-output goods, like automobiles, radios, typewriters, electric motors, refrigerators, and tires.

If you ask a printer to print some personal letterheads or circulars, you will be told that the price *per unit* is lower, the more you buy. Aircraft companies know that the average cost of a jet plane is cheaper if they can produce one hundred than if they produce only ten. Ford knows that the average cost of a car is lower for half a million than for one hundred. Polaroid cameras are cheaper if several thousand are produced rather than a hundred.

If larger-volume production is cheaper *per unit* than small-volume production, *standardization* of products is implied. People who want individually styled or custom-built goods will face higher prices. We should expect to see many people using standardized goods, as they in fact do with automobiles, shirts, shoes, watches, airplanes, etc., because of the cost-reducing effect of a larger volume. A country with a large population can take greater advantage of this cost-reducing effect since it can produce in larger *volume*. This effect of a large market in reducing costs is one of the major advantages of the United States over smaller countries. Larger markets permit greater specialization and mass-production economies.[4]

Annual changes in automobile models prevent costs from falling for *particular* models. Then why change models every year, if that is more expensive than keeping the same model for a larger scheduled volume? There are two reasons: (1) The percentage decrease in average cost is related to the *percentage* change in output volume; therefore, the cost reductions are very small for increases of an already very large volume. A 10,000-unit increase over 100,000 is only a 10 percent increase, whereas it is a 100 percent increase over 10,000. American producers therefore change models more frequently than is done in smaller countries. (2) Tastes change, new ideas occur, improvements in technique must be incorporated if a producer is to continue to have a profitable business.

Exceptions to the average cost-reducing effect of larger volume: exhaustion of raw materials. Not for every good does a larger volume yield lower unit costs. Sometimes as a larger volume is contemplated, more cheaply available raw materials are used up, and resort must be had to more expensive ores and raw materials. For example, the production of oil is now characterized by deeper drilling, in more remote areas. Fortunately, however, technological progress and growth of our wealth have more than offset that exhaustion of easily available raw materials—because men were induced to use the

[4] Yet the *amount* produced is not a simple concept; for example—with an airline, is the amount of the service the number of passengers carried in a year, the number of plane flights per day, the number of seats per flight, the speed of a flight, or the number of years of service? Obviously, it comprises all of these. Or take a hospital; is the output the number of patients, the number of beds available, the number of patient-days of service, the number of operations, the number of cures? For cars, is it the quantity of any one model, the number of models, the speed with which the cars are produced? It is all of these. Any well-specified production program must stipulate several characteristics that constitute the product and its "amount."

easily available materials first. Had they instead been worried only about "conservation," they would have used resources at a lower rate, with the result that income would have been lower; and hence not so much could have been devoted to investment, technology, and research.

The advance in technology and supply of capital goods has meant that, despite the relative decrease in existing amounts of some raw materials (iron ore, coal, wood), many goods are producible at lower costs than formerly, when "cheaper" sources but poorer technology and less wealth were available. Perhaps man has been lucky so far in the race between technological knowledge and depletion of natural resources, but, whatever the reason, the fact remains that technology and growth of capital from saving and investment have more than offset the increased difficulty of obtaining some raw materials and have increased the stock of existing man-made wealth by a more than offsetting amount. It is profitable *investment*—rather than conservation of natural re-
8, 9, 10, sources—that increases the wealth of future generations. Conservation, as we shall see
11, 12 more clearly later, can mean less *income*, not more saving.

Speed of Production and Cost

The faster a *given* volume must be produced, the greater the total, the average, and the marginal costs. This was illustrated in our earlier examples of a five-person, two-goods world. A larger *rate* of output of Y involved a greater rate of sacrificed X. One might have thought that since the same volume of output is being produced, the same stock of materials will be used up, whether it be produced quickly or slowly. However, a higher rate of production uses more resources *at the same time*, thus requiring resort to relatively less efficient resources.[5] Furthermore, the resources insist on higher pay for overtime because the sacrifice of leisure is increased. This is called "increasing costs" with higher rates or speed of production.

Effect of different rates of output. The relationship between costs and output in Chapters 12 and 13 showed a *rising*, not a falling, marginal and average cost as output was increased. Can this be reconciled with the present decreasing marginal and average costs as output increases? Yes, and the answer lies in the ambiguity of the word "output." In earlier chapters we were increasing the daily *rate* or speed of output. Here, we have been increasing the *volume* while holding the daily rate constant. But we can change the rate. One can produce one thousand houses in one year or in ten years; in each case, volume is the same, but the rates differ. And one can produce one house in three months or ten in thirty months; here, the rate of production is constant, but the volumes differ.

The way total cost changes with changes in the projected volume can be made clearer by a graph. In Figure 15–1, the curve MC indicates the *addition* to total cost for unit increases in volume. This is a graph of the "marginal cost of extra units of volume." If it were a horizontal line, it would mean that a unit increase in the volume raises total cost by a constant amount. But a *downward*-sloping line indicates that unit increments of volume can be produced at decreasing increments to total cost.

The *average* cost per unit of volume for different programs is also shown. For larger

[5] Remember the analysis of Chapters 12 and 13 and the reason given there for the rising marginal costs of higher rates of output.

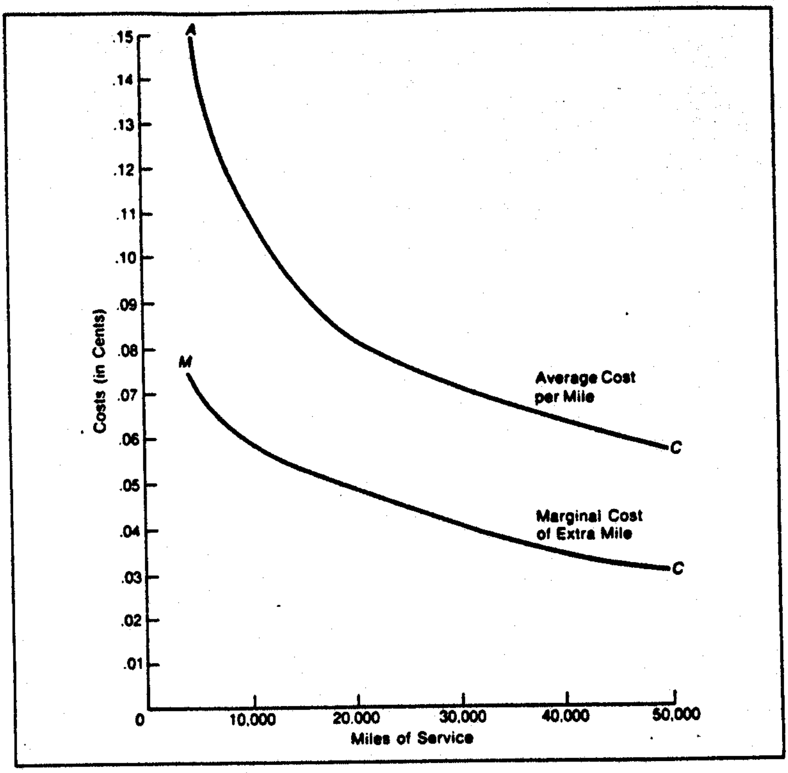

FIGURE 15–1. Marginal and Average Cost per Mile of Service (at Constant 10,000 Miles per Year Rate of Service)

A greater volume of output (in miles) results in a lower cost per mile. An increase in programmed miles of services results in cost increase, but extra cost decreases with increased mileage. These costs are valid if rate of speed of performance is not increased; increased mileage is obtained by using equipment over longer periods of time.

volumes the cost per unit decreases, possibly to some ultimate lowest value. This is, as said earlier, the *economy of mass* or *volume production*. The increase in volume is obtained by lengthening the run of production while holding the rate of production constant.

Why average costs fall with larger volume. (1) Variety of Techniques. If we now recognize that it is impossible to divide some complicated machines into miniatures that would produce just one item, we can see that what can be used economically for larger volume may not be economical for small volume. On the other hand, what is possible with small volumes can be replicated (at the same *rate*) to get the bigger volume. But we can't miniaturize or subdivide in the opposite direction. Thus, if any technique results in lower costs for some large volume, there is not necessarily a way to use this technique at lower volumes too.

A case in point is the "initial setup" cost. For a large volume, this can be very large; if that same technique were used for only a small output, the costs would be catastrophically high. Therefore, large initial or investment cost will be observed only with large volumes. An example is the transport of oil from wells to refineries. If the well owner believes the well will produce about 100,000 gallons before exhaustion, he might ship the oil by truck—shipping, say, 1,000 gallons a day for one hundred days. But if he thinks he will get 1,000,000 gallons, at the same rate of 1,000 per day, he will use either truck or pipeline. Suppose the pipeline is cheaper for 1,000 days (at the rate of 1,000 gallons per day) but more expensive than a truck for only one hundred days. Depending upon the volume (not the daily rate) of oil to be transported, the selected method will be different, with the larger volume having less cost per gallon transported.

(2) Learning. Another possible explanation is called the "learning" factor. Improvement by experience is evident in managerial functions, production scheduling, job layouts, material-flow control, on-the-job learning, and physical skills. The rate of learning may be greatest at first and then reach a plateau; but, in any event, the larger the volume of output, the more opportunity for learning and hence the lower the unit costs of larger outputs.

If one is *allowed* longer time to do something, it will not cost him more to do it—and usually it will cost less. If he wishes, he can do it as early as is most economical. By obstinately (and inefficiently) delaying his production, or starting it too early, he could incur various storage costs. But the proposition here is that allowing more time *within* which to efficiently perform some task or produce some output will result in costs that certainly are *not* higher, and most likely lower. The less time he is allowed, the smaller is his range of options and the less he can utilize any available cheaper means of production.

13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27

Proportionate Increases in Both Rate and Volume

For many goods, a common feature of production is a joint change—indeed, proportional change—in *both* the rate and volume of an output program. For example, *if the length of the production run is constant,* say one year, then a higher rate in that period will also mean proportionally larger volume. An automobile manufacturer can contemplate *rates* of output from 1,000 a month to 50,000 a month for one year. If any of these rates persists for a full year, the range of volumes implied is from 12,000 to 600,000 cars. In these cases, one can speak either of the annual rate (*lasting for a year*) or of the volume of a program, since both increase proportionally. Hereafter, unless specified to the contrary, we shall assume this to be the case.

Higher rates of output and larger volumes both increase *total* costs, but by different amounts: they have *opposite* effects on *average* cost per unit of volume of output. Larger volumes reduce average costs, while higher rates raise average costs per unit of any volume produced. Which effect dominates when both the rate and the volume increase in the same proportion—that is, when the total volume is increased but is produced in the same interval of time? The average cost may fall as both the rate and volume of output are increased at lower output ranges, but larger rates of output, even though accompanied by a proportionate increase in the volume, will ultimately dominate and cause higher average costs.

Table 15–2 shows how total costs vary for different output programs in which the volume *and* the rate of production differ in the same proportion. The data are graphed in Figure 15–2. For example, at point *A* the *volume* is 5,000 miles at a *rate* of 2,500 miles per year; the total cost is $500. At *B* the volume is 10,000 miles and the rate is 5,000

TABLE 15–2. Costs of Alternative (Two-Year) Ouput Programs

	Output (Miles)	Rate per Year	Costs		
			Total	Average	Marginal
A	5,000	2,500	$ 500	10.0¢	9.0¢
B	10,000	5,000	900	9.0	7.7
C	15,000	7,500	1,200	8.0	7.0
D	20,000	10,000	1,680	8.4	9.0
E	25,000	12,500	2,200	8.8	11.0
F	30,000	15,000	2,800	9.3	13.0
G	40,000	20,000	4,200	10.5	16.0

Output is miles of distance at rates of miles per year such that distance is yielded in exactly two years. Both distance and rate increase proportionally from *A* through *G*. Total costs are plotted in Figure 15–2, and average and marginal costs are in Figure 15–3. The output increase of 5,000 miles, from 5,000 to 10,000, raises total costs by $400. Dividing this increase by 5,000 miles gives 8 cents a mile—a crude approximation to the marginal cost for one mile of service in that interval. The tabled numbers are correctly computed marginal cost from more detailed information and are centered on the 5,000th mile, the 10,000th mile, etc. You could estimate the marginal costs around 30,000 miles by getting the increase in cost from 25,000 to 30,000 miles and dividing by 5,000 miles (which gives 12 cents), or by dividing the increase in costs between 30,000 and 40,000 by 10,000 miles (which gives 14 cents). The marginal cost at 30,000 miles is 13 cents.

miles per year—both twice as big as at *A*. The total cost is $900, not quite twice as large. And at *G* the costs are for an output program with volume of 40,000 miles at the rate of 20,000 miles per year, each of which is eight times larger than for program *A*. The total cost of that bigger program is $4,200, more than eight times as large; now the rate effect has dominated the volume effect.

The marginal cost curve, *MC*, in Figure 15–3 shows (by its *height*) the increase in total cost between two output programs differing by one mile of distance (volume) and 1 mile an hour of speed of production per two years. For example, the marginal cost at 20,000 miles of service is 9 cents. This means that if we were to produce 20,000 miles in two years at a rate of 10,000 miles per year, the total cost would be greater by 9 cents than for a program of 19,999 miles in two years (at the rate of 9,999.5 miles per year).

Converted to average cost per mile of service, the costs are shown by the *AC* curve in Figure 15–3 for different output programs. The total cost of 5,000 miles (at 2,500 miles per year for two years) is $500, which gives an average cost per mile of 10 cents, shown as point *A*. The total costs of 20,000 miles in two years is $1,680, which gives a per-mile cost of 8.4 cents. For 40,000 miles in two years the total cost is $4,200, with an average per-mile cost of 10.5 cents. These per-unit costs are pulled down by the effect of large volume production, but they are pushed up by the effect of higher rates. The average cost per unit of output (mile) curve for different possible output programs will be roughly U-shaped, with a falling segment followed by a flatter, possibly horizontal, section and ultimately rising more and more sharply.

Figure 15–3 is a useful analytical diagram and should be thoroughly understood. The shape and position of the curves are for our present automobile example. Obviously the diagram will differ for other situations. Which features will persist? For generality, we show the curve as U-shaped—with nothing implied about the *length* of the downward,

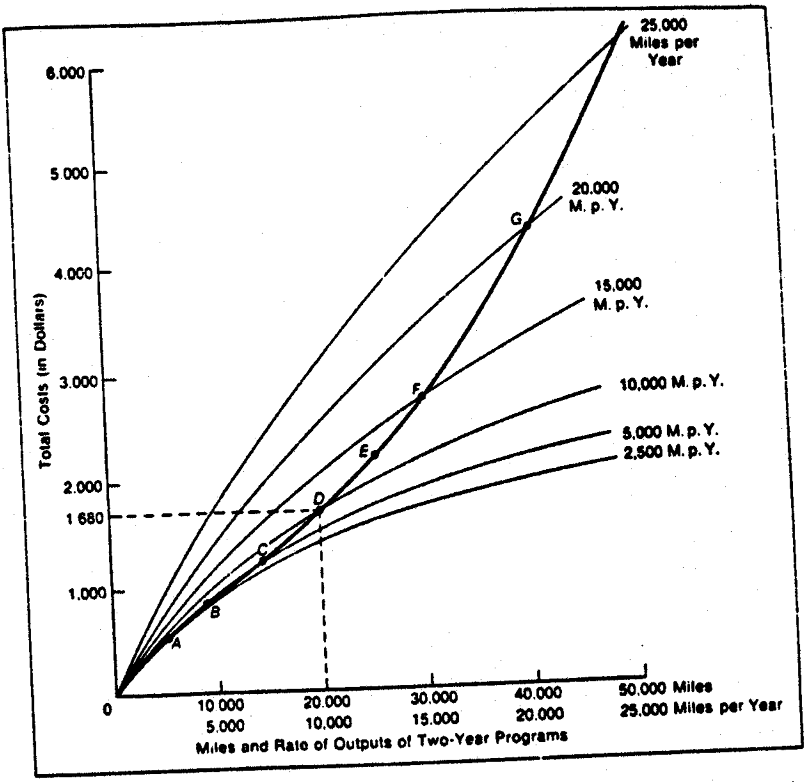

FIGURE 15–2. Total Costs of Two-Year Programs, with Proportional Increases in Both Volume and Rate

Rising curve shows how total costs increase with *proportionate* increases in rate and volume of output. Increase in total cost is always "positive" but increase diminishes at first till about point *C*, and then increases in total cost with each increment as output becomes greater and greater (shown by increasing slope of line). Light lines in background are curves showing behavior of costs for increases in mileage but at constant rate (speed) of output during production.

flat, and rising segments. There may not always be a falling segment for small outputs. But an ultimately rising segment always will occur for the larger outputs (for the effect of faster speeds of production will dominate any volume effects for larger joint rates and volumes). Thus the average cost curves of all production situations with joint proportional changes in volumes and rates have at least this one property in common: for sufficiently large outputs they will rise and rise with increasing rapidity.

The *marginal* cost curve always cuts through the minimum point of the average cost curve. If you remember what marginal costs are, you will see why. Marginal costs are the increment in costs for a unit increment of output. If that increment of cost is greater than the average cost of production, that will increase costs by more than the average. Since more is added (to the total) than the current average cost, the average cost is pulled up. Like taking another test—if your marginal score (the score on this new test) is higher than your average, it will pull up the average. And if it is lower, it will pull the average down.

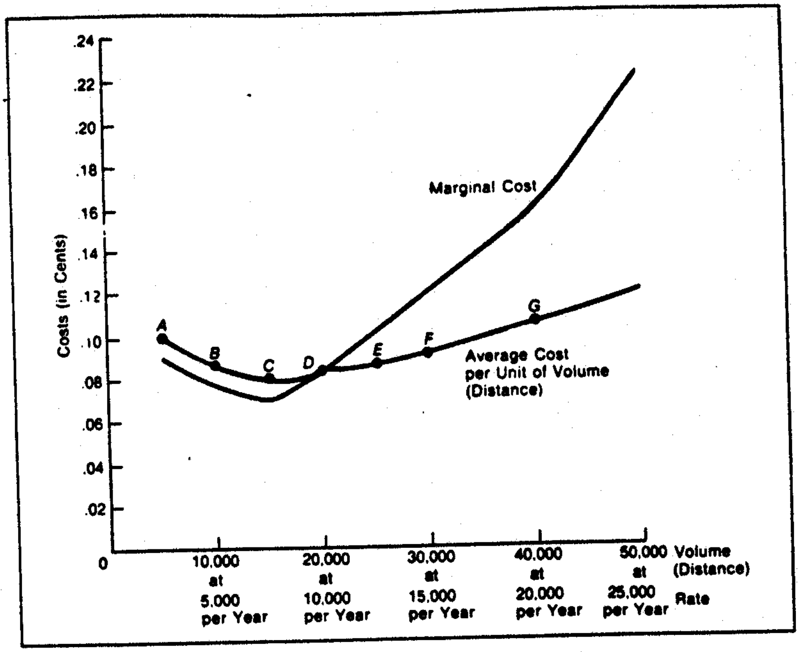

FIGURE 15-3. Average and Marginal Cost of Two-Year Program with Joint Volume and Rate Increases

Total costs of Figure 15-2 have been converted to average costs per mile of service and plotted as average cost per unit of volume (distance in miles). Points on total cost curve of Figure 15-2 are shown here as corresponding points, lettered *A, B, C*, etc. Notice that average costs at first fall for smaller outputs and then begin to increase for larger outputs. Marginal cost curve shows increase in total cost with each increase in output of one mile by increasing speed just enough to get out one more mile in the two year period. For example, at 30,000 miles of service at rate of 15,000 miles per year, the cost per mile is shown by point *F* and is about 9 cents per mile. But an increase in the number of miles from 30,000 to 30,001 by increasing speed sufficiently will increase total cost about 13 cents (depicted by height of marginal cost curve above 30,000 mile point on horizontal axis).

Though marginal cost may be decreasing at small outputs (where volume effect dominates the speed) it will, possibly after a long flat portion, certainly rise at large joint speed and volume of output. This behavior is similar to the shape of the average cost curve. If the marginal cost curve, starting out from zero output, *always* rises—the average cost curve will be below the marginal cost curve and rising. (Can you see why? 28
Recall the analogy of your test scores.)

Timing of Production: Long Run and Short Run

Still another dimension of the program affects costs—the date or time at which the output is to be provided. Hasty (though not reckless) output adjustments, whether made with existing equipment or with newly acquired equipment, are more expensive because revisions of equipment are more expensive the faster they are made. In other words, for a specified cost, the inputs are less variable in a shorter than in a longer interval. Turned around, this means the physical constraints are more binding for immediate adjustment.

Deferred output programs cost less than those initiated more hastily with existing equipment, unless the existing equipment just happens to be optimally suited to the proposed output, in which case the cost is no greater. Figure 15–4 shows two average-cost curves, a short-run curve giving the costs for the output to be produced shortly and a long-run curve for the later output. For all outputs except the one for which the existing equipment happens to be optimal, the long-run curve lies below the short-run curve.

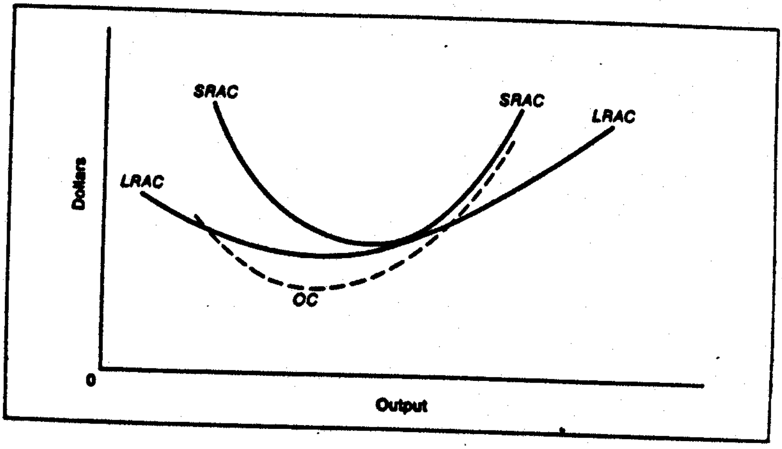

FIGURE 15–4. Long-Run and Short-Run Costs

Curves show average costs of long-run output program and of short-run output program, the former being the lower limit of costs achieved by deferring the output program. Output at which both curves are tangent is output for which existing equipment is optimal. For any other output, a different set of equipment would be more economical, as shown by fact that the long-run cost curve lies below the short-run cost curve for all other outputs. Curve labeled *OC* shows average per-unit operating costs with existing equipment; it excludes from *SRAC* all the costs (per unit) that would be incurred if possession were continued and if no output were produced. (See pages 256–257.)

There is a limit to how low costs can be made by deferring the output; that lower limit is called the *long-run cost*. Here we shall show just the two extreme cases, the immediate (called the short run) and the long run. Intermediate cases are ignored for present expository purposes.

Carefully note that two curves do not mean there are two costs for a given program, a short-run cost and a long-run cost. Rather there are two different programs, a short-run program and a long-run program, each with its own cost.

Why a long- and a short-run cost distinction? Because we must allow for the fact that the responses of production to changes in demand and market price usually extend over time, and the more deferred response usually comes at a lower cost (and is larger).

Marginal costs of short and of long run. The short-run and the long-run *marginal* cost curves are shown in Figure 15–5, which is otherwise the same as Figure 15–4. These curves, you will recall, show by their height the increment in cost for producing a larger output (by one mile in the two-year period). The short-run marginal cost rises more rapidly, which reflects the inappropriateness of existing equipment for output programs substantially different from that for which the equipment was intended.

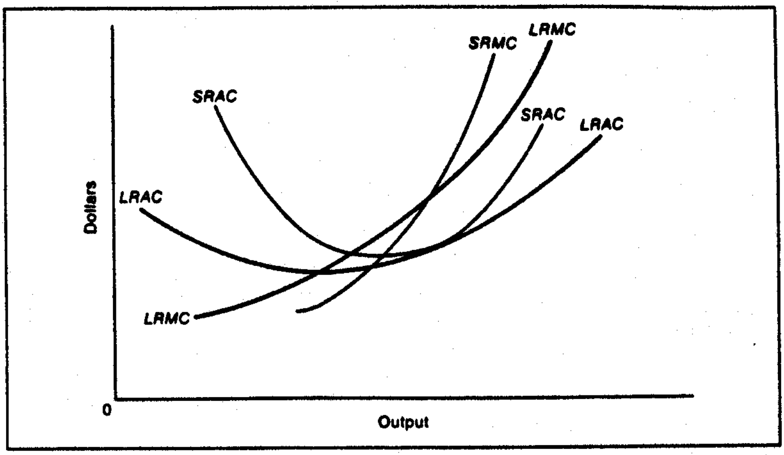

FIGURE 15–5. Marginal Costs of Short-Run and Long-Run Output Programs

This is basically the same as Figure 15–4, with marginal cost curves added (and OC omitted). Although short-run average costs (for a short-run program) are always larger than for a long-run program, marginal costs of short-run output program changes can be less than for long-run output changes.

Short-period, short-run, long-period, and long-run outputs. "Short period" means a short-*lived* run of production—not a short time until production started. If we could create conventions, we would call one the short-period output (*lasting* for a short time) and the other the short-run output (*beginning* after a short time). But convention is too strong; both cases are called the short-*run*. So from the context you must discern which is meant. A short-period output can have a per unit cost that is lower than for short-run outputs and even less than for the long run—since it is a cost of an output different not only in timing but in length of output. (Since it is short lived, we can ignore the costs of some of the activities that would have to be met if production continued for a longer interval—for example, *acquisition* costs of new equipment.)

Another convention bears noticing. Usually in elementary texts the "short run" is used also to refer to an output produced under conditions in which not all the inputs can be adjusted, i.e., in which one is fixed and invariant. Changes in output, in that case, can, by definition, be achieved only by varying *some* (not all) of the inputs, which implies higher costs than if *all* the inputs could be adjusted.

In fact, *all* inputs *can* be varied in any interval, but the costs of varying some inputs immediately increase so much more rapidly than for delayed variations that almost certainly they will not be varied quickly. For example, a new factory building could be constructed or purchased in a few weeks, but it would cost a lot less if done in a few months. On the other hand, there is not so much difference in the costs of getting more labor or raw materials in a few weeks instead of a few months. Thus, rarely will it be economical to increase all inputs at the same rate. Factory space or equipment will usually be increased less rapidly than labor. At an extreme, as a limiting case, we may assume it won't be changed at all, i.e., is "fixed."

Hence if your instructor refers to short-run *intervals* as those in which some inputs are fixed, remember this limiting assumption is an expository simplification to avoid more complex features that may usually be ignored in elementary courses. For students who progress to more advanced work, the correct, more general interpretation must be used.

Costs Relevant to Entry and to Shut-down Decisions

Long-Run Entry Cost

What is the minimum amount of revenue in present-value measure that you must receive to make it worthwhile to produce the output program—20,000 miles of service over a two-year interval? The answer is $1,678.90 or 8.39 cents per mile. You would not consider entering this business unless you expected at least 8.39 cents per mile for the rent of your car. That is called the *long-run* minimum per-mile cost of that complete program.

To Continue or Not to Continue Production

If the price received for a mile of your car's services stays above 8.4 cents, you will cover your costs. But if the price is lower, your business will have lost wealth, and you may decide on some changes.

1. Should you stop operations temporarily, awaiting a return to better times?
2. Should you continue operating temporarily at least, making the best of the situation?
3. Should you immediately get out of business?
4. Or should you change the scale of your operations?

This last question will be discussed in the next chapter. For the present, consider the first three. Since we assume you entered business to enhance your wealth, you should do whatever will preserve your wealth, now that the former hopeful expectations are replaced by the less favorable price.

1. If you continue, instead of shutting down immediately, costs will be incurred at the rate 7.4 cents per mile; this excludes the cost of *acquiring* the car, since you already have incurred the initial $200 cost (between the $2,000 purchase and the immediate $1,800 resale price which amounted to 1 cent per mile for the projected 20,000 program). Any amount over 7.4 cents per mile would bring in more than it would cost for the next two years. Your initial entry cost, which is past history, is at least being partly covered if you

get anything over 7.4 cents a mile. When the time came to get a new car, you might get out. So, if price is above 7.4 cents per mile, continue to operate for up to two years; do not shut down immediately.

2. But if price fell below 7.4 cents, and you thought it was a *short-lived* dip, you might temporarily stop operating the car, awaiting the return shortly to better times. Only if price doesn't fall below 3.2 cents a mile, would it pay to continue to operate the car for a while. Why? Because any amount over 3.2 cents would cover the costs of *operating* the car, *given that you are going to keep it for better times*. Just keeping the car is costly—costs of storage, depreciation, taxes, insurance, and license will occur. Whether we operate or not (while keeping the car), we will incur those costs, and they are assumed to be 4.2 cents a mile of the forsaken miles if we don't use the car. So the cost of *operating* the car, *given* that we are going to keep it, is 3.2 cents per mile—the difference between 7.4 and 4.2 cents per mile. That 3.2 cents is the operating cost per mile of service—above or net of the costs of keeping it.[6]

3. If price falls below 3.2 cents, shut down immediately. Whether you do so permanently or temporarily depends upon how long you expect the price to stay low.

4. The preceding discussion ignored the determination of the output size; we simply assumed 10,000 miles per year for two years. We did so purely for an expository purpose, i.e., to indicate some of the decisions other than changing the output that must be constantly weighed. Probably the decision most frequently assessed is the determination of the quantity of output. To see how this decision depends upon market price and costs, we must know how costs depend upon the quantity of output.

Joint Products with Common Costs

"Joint and variable" outputs. Production processes do not all yield only one product. Many give several *joint* products. Beef and hides are joint products of cattle. Cotton and cottonseed oil; kerosene, fuel oil, and gasoline; butter and milk—these are joint products. They are interdependent in supply; generally, more of one involves more (or less) of the other. More beef also yields more hides. More cotton yields more cottonseed oil; a higher price for one of the outputs will, by inducing a larger output of cotton, also lead to an increased output of the joint good. Thus, the supply of a good is dependent upon not only its own price, but that of other goods—especially of joint-product goods.

Yet we mustn't overdo this jointness; even for these joint products, more of one can mean less of the other. Beef and hides, although joint products, are substitutes in that there are different breeds of cattle, yielding different ratios of beef to hides. One could increase the ratio and, in fact, get more hide and less meat, by selecting different breeds and slaughtering ages. These propositions hold for gasoline, kerosene, and fuel oil—all of which are obtained by refining crude oil. Different refining methods yield different ratios of output. Cotton and cottonseed are also variable, though joint, products. Depending upon which of the joint products one is interested in, the other is often called the by-product.

[6] As a matter of fact, if price fell below 3.2 cents per mile, it might also pay to continue to operate temporarily. If the service is provided at a lower rate than at 10,000 miles per year, the costs will be lower. If we anticipate the principles to be explained in the next sections, it can be shown that the costs per mile of service would be as low as 2 cents for a lower rate of output, given the existing equipment. Operating less intensely means slightly lower direct operating costs so that the costs can be shaved down to as low as, say, 2 cents per mile for temporary operation.

Impossibility of allocation of common costs. If two products are produced jointly from a "common" input, how does one allocate the costs of the common resource to each of the joint products? If, for example, hides and meat are produced from one steer, and if the feed and care of the steer is a common input or a common cost to both products, what portion is the cost of the hide and what portion is the cost of the meat? If an airplane carries passengers and freight cargo, what portion of the common costs of gasoline, labor, and facilities is assigned to each? Can a "common" cost be allocated among joint products?

Depending upon which product is treated as a residual or by-product, a different allocation of costs may be obtained. In effect, by calling one product the by-product, one is implicitly assigning all the "common costs" to the other, the "basic," product. But this, of course, is merely an arbitrary allocation, depending upon which product one calls the basic product. If costs can't be allocated, how can one tell what prices to charge? How can a producer tell whether he is making a profit on each item? How can he tell how much to produce? Things seem to fall apart at the joints. In fact, however, the presence of costs which cannot be allocated uniquely to the joint products does not upset anything (except possibly some accountants).

Pricing and output decisions are independent of assignment of common costs. One purpose of market prices is to allocate the existing supply of product among the competing claimants, and another is to induce production. Both tasks can be performed by the same market price, even if common costs cannot be allocated. The "rationing" price, as we have seen, does not depend upon how costs are apportioned; it depends upon demand and supply. What about the second function—that of inducing production of goods? There is no necessity to allocate the common costs to the joint products. All that is necessary is a comparison of the total costs of the whole *set* of joint products with the total revenue from their sale. If the total revenue does not cover the total costs, some producers will be induced, by a loss of wealth, to stop production, leaving a smaller output and resultant higher prices of the various joint products, until the price is high enough to cover the total costs of the entire set of joint products.

Still unsolved is the question of the rates of each of the joint outputs by those firms that are profitable. The producer still does *not* have any use for an average cost of each joint product based on some allocation of the common costs. He requires instead a measure of *marginal* costs for each of the joint products. If he expands the output rate of any of the joint products, either singly or jointly, how much do total costs increase? If that marginal cost is observed to be less than the marginal revenue from that extra output, that output will be expanded, assuming the producer wants to increase his wealth. Otherwise, the output will be contracted. In other words, the wealth-maximizing output decision does not require any allocation of common costs to the component products. Only total costs and total revenue effects need be discerned. None of these decisions—pricing or output, or even combinations of inputs—depend upon separability or bookkeeping allocation of the cost of any input shared by the joint products. This is a crucial point. Pricing and output decisions can be made even though one cannot assign portions of costs of a common production input to the products that are jointly produced. Nothing is lost, except an answer to a pointless question: "What is *the* cost of production of *one* of the joint products?" To say that the question is pointless doesn't mean it won't frequently be asked.