

Content Articles in Economics

In this section, the *Journal of Economic Education* publishes articles concerned with substantive issues, new ideas, and research findings in economics that may influence or can be incorporated into the teaching of economics.

HIRSCHEL KASPER, Section Editor

Ten Cheaper Spades: Production Theory and Cost Curves in the Short Run

Richard A. Miller

Dennis Robertson pondered years ago how to calculate the marginal productivity of 10 hole diggers.

If ten men are to be set to dig a hole instead of nine, they will be furnished with ten cheaper spades instead of nine more expensive ones; or perhaps if there is no room for him to dig comfortably, the tenth man will be furnished with a bucket and sent to fetch beer for the other nine. (Robertson 1931, 226)

“Ten cheaper spades,” equal somehow (as required by the marginal productivity calculus) to 9 more expensive spades, hardly reflects industrial reality. What to do with the 10th shoveler? A different, more correct solution would be to send him to the tool shed for a 10th spade.

Turgot, Malthus, Ricardo, and others recognized diminishing marginal physical productivity (MPP) of a variable factor used with one or more fixed factors in agriculture. Increasing increments of labor-seed-fertilizer applied to the fixed-factor land eventually produce a decline in the marginal product. Here diminishing returns¹ is an apt description. But agricultural analogies will not support diminishing returns in a manufacturing context. In agriculture, there is no need to distinguish the stock of land from the flow of services from land. Once a field is plowed, fertilized, and planted, the land provides services continuously—no

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shutdowns. Ricardo's original and inexhaustible powers of the soil are not turned off for the night when the farmer leaves the field.²

This simple observation strikes at the heart of current microeconomic theory, where diminishing returns play a central role.³ In a competitive factor market, diminishing returns support the negatively sloped demand for that variable factor. Similarly, the positively sloped competitive supply, derived from competitive firms' individual marginal cost (MC) curves, rises because of diminishing returns. The slopes—rising MC and falling MPP—are logically necessary to describe economists' crown intellectual jewel: perfectly competitive general equilibrium, stylized in economics textbooks by the circular flow of economic activity, from which monopoly, public goods, and externalities are banished, where markets (and information) are complete, and in which all inhabitants are price takers.

This story is universal. Introductory micro textbooks devote the first 8 (or 12) chapters to competitive markets.⁴ Then, after competitive general equilibrium is extolled for its optimality properties, the problems or exceptions or modifications compelled by reality appear: monopoly (natural and otherwise); externalities; asymmetric or imperfect information; public goods (all as market failures); and perhaps also income distribution, technical change, health care, cities, and taxes, all as issues appended to the circular flow.⁵

But what about the reality and the logic of diminishing returns and the law of variable proportions, so essential an element in our saga of the competitive circular flow? Two additional problems disturb our standard narrative of perfectly competitive markets. First, as taught, increasing then diminishing returns for a firm produce the U-shaped average variable cost curve (AVC), with its associated, rising MC curve piercing the minimum. This prediction is not supported by over 60 years of empirical studies of short-run cost curves, studies which almost invariably show horizontal $AVC = MC$ over a significant range of possible rates of output.

Second, as taught, the diminishing returns derivation (the partial derivative) requires that the fixed factor, capital (or land), be held constant, as in Robertson's 10 cheaper spades.⁶ In the short run, the stock of capital is held constant (fixed) but that does not necessarily, or even generally, imply that the flow of capital services is constant. The production function is (or should be) defined as *output as a function of input services*: Output per time period is a function of labor services (man hours per time period) and capital services (capital hours or machine hours per time period).⁷ The capital *stock* may not be only fixed but indivisible, and is in the short run; but capital *services* may be—and usually are—perfectly divisible, so that any number of machine hours, from 0 to 168, may be employed during the time period of one week.⁸ Many production functions, such as automobile assembly, steel making, and transportation by driver (labor) and automobile (capital), involve a fixed capital stock, but the flows of capital services as well as labor services are variable. Different rates of weekly output for automobiles, steel, and transportation are accomplished by altering the weekly use of both capital services and labor services, with the capital stock remaining constant. The automobile can be garaged for the entire week, or it can be driven nonstop across the

country and back. Capital and labor, both services, are *both* variable in the short run. The law of variable proportions is then brought into question; if the capital services and labor services are used in fixed proportions in the short run, then this “law” absolutely fails to describe productive reality. Empirical work suggests that much short-run variability in output in U.S. manufacturing derives from using variable factor services, but those services are used in fixed proportions.

Mine is a revisionist tale of simple microeconomic theory, intended to provide theoretical support for these two empirical results that conflict with the micro theory currently inflicted on students.

MANUFACTURING REALITY

Good theories possess two attributes: They accurately and simply describe or explain nontrivial phenomena, and they make accurate predictions. The diminishing marginal physical productivity theory passes neither test, at least in manufacturing. To adjust output in the short run, firms do not generally employ all available capital services whatever the amount of labor employed. Also, AVC is not smoothly U shaped but is, in fact, horizontal (up to some measure of capacity).

Consider first the short-run predictions from marginal productivity theory: the U-shaped AVC and the associated MC. A number of studies have examined the shape of the AVC for specific plants; the strong consensus is that AVC is horizontal and hence coincides with MC up to some capacity measure. The following are three examples from studies by economists who have summarized some data and surveyed some studies:

1. Joel Dean’s studies of a furniture factory, a leather belt shop, and a hosiery mill:

For each of the three factories studied, total cost rose in a straight line as a function of the rate of output over the range of output observed. Hence marginal production cost [also AVC] was constant over the actual operating range for the period studied. . . .

For economic theorists, the horizontal statistical marginal cost curve is what Charles Fort called one of the “damned facts—the facts that do not fit in.” (Dean 1976, 17, 29)

2. Edwin Mansfield’s survey of empirical cost studies:

[An] interesting conclusion of the empirical studies is that marginal cost in the short run tends to be constant in the relevant output range.

. . . . [T]he short-run marginal cost function often seems to be horizontal, not U-shaped. (Mansfield 1988, 223, 228)

3. Joe S. Bain’s survey:

One striking finding of such [empirical] cost studies has been the apparent linearity, over wide ranges of outputs, of the short-run total production cost functions of observed firms, implying a constant short-run average variable and marginal cost except at extremely small or large outputs. . . . The resistance offered [by economists to this empirical finding] suggests that some critics have been unduly enamored of

the symmetrical U-shaped [unit] cost curves of conventional *a priori* analysis. (Bain 1948, 140–41)

Other economists have reached similar conclusions. (Johnston 1960; the National Bureau of Economic Research 1943; Walters 1963). The U-shaped AVC prediction has not been generally supported by the data.⁹

Second, consider how firms actually alter inputs to change output in the short run. Suppose that a plant with capital goods consisting of 10 identical “machines,” say spades, produces a product, holes in the ground. In the short run the plant is fixed at 10 spades. The long-run capital budgeting decision has already determined the number of spades and their particular configuration of spoons and handles. To produce holes, each spade requires one worker. Output (Q) is a function of labor input (L) and capital input (K); Q , K , and L all are flows, of output and of inputs, that is, flows of labor services, of capital services, and of output. The production function coefficients provide the quantitative links among Q , L , and K . K and L are used in fixed proportions in this example, one shoveler per spade. Now how in the short run is the rate of output (holes per day) altered? At any one time, a maximum of 10 shovelers can be accommodated with the capital stock of 10 spades. An increase in the daily output is accomplished by overtime or by a second or third shift; reduced daily output is accomplished by laying off some shovelers and an identical number of spades. The flow of services from both inputs is increased or reduced in proportion; spade-capital and shoveler-labor remain employed in fixed proportions, as adjustments are made to the rate of output. Moreover, homogeneous shovelers, homogeneous spades, and constant factor prices together imply a horizontal AVC up to daily “capacity,” the output produced by using 10 spades for three 8-hour shifts with 10 shovelers per shift. Of course, holes in the ground can be dug using alternative techniques. Laborers can be provided with other forms of capital, say backhoes or trowels. The choice of which technique (capital-labor ratio) is used depends on relative factor costs. But that is a long-run consideration. Once the spades (or backhoes or trowels) are acquired to dig holes, the capital (*service*)-labor (*service*) ratio becomes fixed. In contrast, the short-run capital (*stock*)-labor (*service*) ratio will change if the rate of output is altered.

As part of a continuing study of capacity utilization, economists at the U.S. Bureau of the Census and the Federal Reserve Banks are investigating how U.S. manufacturing firms actually adjust output in the short run. In short, their results strongly support the fixed proportions story of flows from spades and shovelers (Mattey and Strongin 1997; Beaulieu and Mattey 1998; Corrado and Mattey 1997). They describe two primary manufacturing processes, pure assembly and pure continuous processing. In pure assembly manufacturing, “shutdown and startup costs are low and all output adjustments are accomplished through varying the plants’ work periods” (Mattey and Strongin 1997, 3). In pure continuous processing manufacturing, “shutdown and startup costs are large and none of the output adjustments are accomplished by varying the plants’ within-week work periods,” but by shutting down a portion of a plant (Mattey and Strongin 1997, 3). In both cases, plants have been designed to operate with a fixed amount of labor input, hence short-run adjustment in output is accomplished by maintain-

ing a constant ratio of capital services to labor services, increasing or decreasing both in proportion.¹⁰

Automobile assembly provides a good example of a pure assembly and hence a variable work-period industry. Work-period adjustment is accomplished largely by adding or dropping shifts and by the length of shutdowns, including extending the period for model changeovers, if excessive automobile inventory needs to be worked off. The line speed (the rate at which assembled automobiles emerge off the assembly line) is infrequently altered (Bresnahan and Ramey 1994; Aizcorbe 1992).¹¹

Examples of continuous operation are steel mills and cement plants. In each industry output is reduced by shutdowns of some units in each plant or of an entire plant, such as furnaces in steel and kilns in cement, rather than by reducing the flow of output from all individual furnaces or kilns.¹² Short-run fluctuations (reductions) in output are accomplished by reducing both capital services and labor services, not labor alone (Bertin, Bresnahan, and Raff 1996; Das 1992).

In short, manufacturing firms generally adjust output in the short run by increasing or decreasing the time in which capital and labor are used together. Fixed proportions seem more suited to describing short-run manufacturing processes than do variable proportions.

LEONTIEF FIXED PROPORTIONS IN SHORT-RUN PRODUCTION

Standard diagrammatic treatment of short-run production and associated cost curves can be modified to allow for fixed-factor (flow) proportions in the short run and to produce a horizontal AVC. In the long run (before capital is acquired and the specific configuration of the capital stock is set), the capital-labor ratio is a variable to be determined by relative factor prices and the long-run production function. Production processes can be planned to be more or less labor intensive (less or more capital intensive), depending on whether labor is cheap or expensive relative to capital. Geometrically, the long-run expansion path is the locus of tangencies of the iso-cost curves and the isoquants; written mathematically as

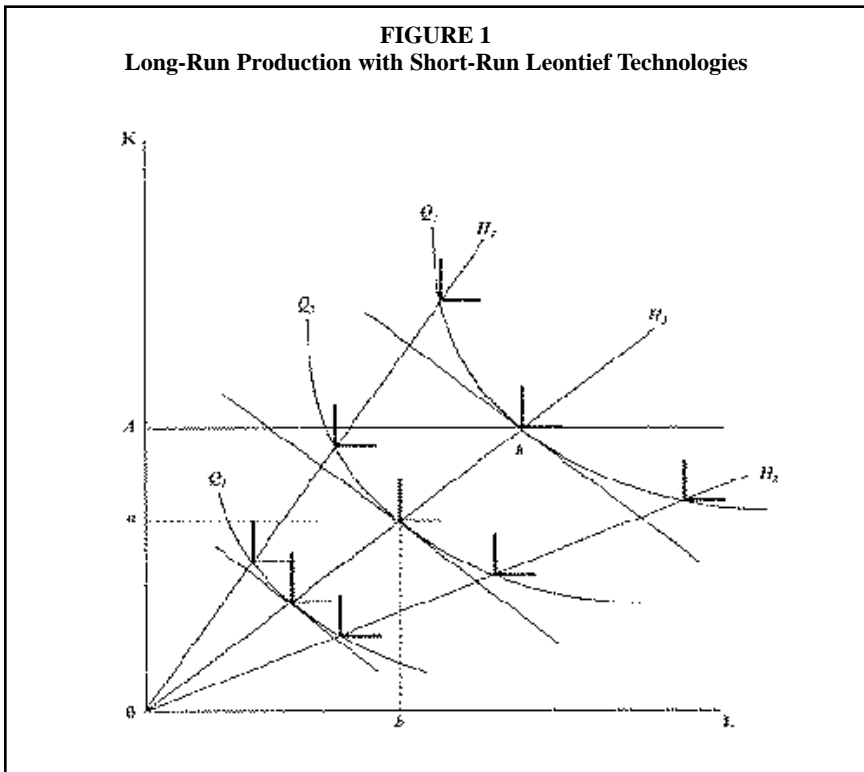
$$\text{Max } Q(K, L) \text{ s.t. } (w \times L + r \times K = \text{constant}),$$

where Q , K , and L are all flows, not stocks, that is, output and services of inputs each with a time dimension. Once the factory is built and the equipment acquired, the capital-labor ratio becomes fixed, and output is varied by employing different amounts of capital and labor (capital services and labor services) in fixed proportions. The rate of output is expanded (contracted) by employing both more (less) labor services and more (less) capital services through the use of overtime or second or third shifts (short weeks or temporary layoffs), where the use of capital (capital services) and the use of labor (labor services) are measured on the y and x axes. That is, the short-run production process embodies fixed input proportions, and whatever opportunity exists in the long run for K - L substitution disappears in the short run. The curvature of the isoquant reflecting long-run elasticity of K - L substitution is replaced by Leontief technology with L-shaped isoquants in the short run.¹³

Three such expansion paths are illustrated in Figure 1 (OH_1 , OH_2 , OH_3), reflecting three different relative factor prices. Each of these long-run expansion paths is the result of constrained maximization, graphically the locus of tangencies of the long-run isoquants and the iso-cost lines, where the slope of the iso-cost lines embodies relative factor prices. If relative factor prices indicate that OH_3 is the relevant long-run expansion path, then the capital stock OA (measured as the maximum flow of capital services per period) chosen for capacity (isoquant) Q_3 produces a short-run expansion path of Oh , along which K and L are used in fixed proportions.

In contrast, the standard short-run expansion path reflecting the law of variable proportions is the horizontal line at A . Diminishing marginal physical productivity of the variable factor (labor services) emerges as the horizontal line at A crosses the long-run isoquants.¹⁴

The implication for production theory is that the smooth isoquants of long-run production functions (reflecting K - L substitutability) are the envelope of L-shaped isoquants reflecting zero elasticity of substitution of K and L in the short run. However, if the size of capital is not continuously variable (truck sizes, saw sizes, or spade sizes may not be continuously or infinitesimally variable but are discrete), then the envelope of those L-shaped isoquants (short-run Leontief technology) is not smooth but is a series of right angles visually resembling saw-teeth



with a curvature to the array of teeth points, similar to Varian's (1992, 5–10) discussion. Each of the three expansion paths (OH_1 , OH_2 , OH_3) in Figure 1 represents three different K - L ratios: OH_1 (a capital-intensive technique) represents backhoes (or chainsaws or big trucks); OH_2 (a labor-intensive technique), trowels (or pen knives or small trucks); and OH_3 , spades (or hand saws or intermediate trucks). The closer capital is to being continuously variable, the more teeth (the more OH_1); in the limit of continuous variability in capital and hence of the capital-labor ratio, the points of the short-run saw-teeth become the usual smooth (and long-run) isoquants of standard production functions (Varian 1992, 105).¹⁵

SHORT-RUN COST FUNCTIONS

Once K is set (the size of the spade, saw, or truck is fixed), then total cost is $TC = w \times L + FC$, where TC , $w \times L$, and FC (fixed cost) are all expenditures per time period, say a week (that is, weekly financial flows). The cost of capital (the cost per week of OA) is fixed,¹⁶ even though capital can be laid off (used less than 168 hours per week), but the weekly cost of labor remains variable—labor can be laid off for part or all of the week and not paid. For the indicated iso-cost lines in Figure 1, the (long-run) expansion path is OH_3 ; if the capital stock providing maximum services of OA is acquired, Oh is the relevant short-run expansion path and h represents full capacity utilization of the OA stock. Along Oh , capital can be laid off (the flow of capital services can be reduced), but the cost of the fixed stock of maximum capital services OA is, by definition, fixed in the short run. For example, suppose a plant possessing weekly capacity Q_3 (at h) chooses weekly output Q_2 ; Ob of labor services is used per week, as is Oa of capital services per week. aA of the available capital services OA is laid off or unused.¹⁷

If the underlying production function displays constant returns along the short-run expansion path Oh (constant returns to capital and labor services), and if labor is competitively available (no monopsony in the labor market), then average variable cost and short-run marginal cost are horizontal and equal for O – Q – Q_3 . Over this range, average total cost, as in the standard analysis, declines up to capacity Q_3 , because average fixed cost is the rectangular hyperbola $AFC = FC/Q$. At capacity (Q_3 at h) AVC and MC turn vertical; this is “flat out” production for either continuous processing or pure assembly operations. These considerations appear in Figure 2, the proffered substitute for our standard U-shaped cost curves for a firm.

Kahn (1989, 57, 59) has sketched this theoretical conclusion:

It has already been indicated that a very common method of reducing output, notably in cotton-spinning and coal-mining, is to close down the whole plant on some days and to work the whole plant for a full shift on other days. . . .

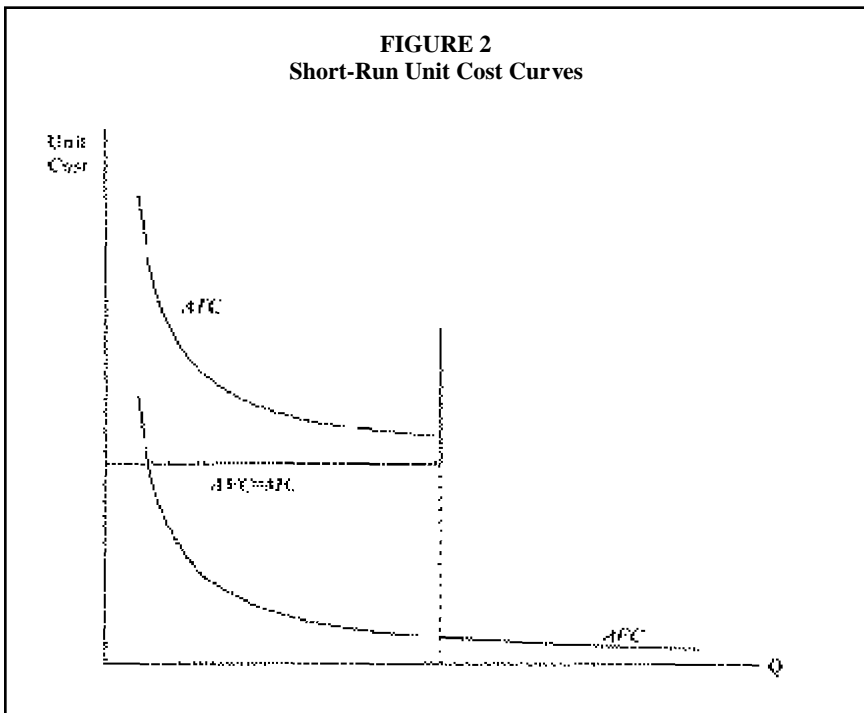
When the maximum possible number of days is being worked each week, output cannot be increased further. The output is now equal to what may be called capacity output. At this point the prime cost curves [AVC , MC] which have hitherto been a horizontal straight line, move up vertically.

The result is thus obtained that the prime cost curve (marginal or average) has the shape of a laterally inverted letter L. . . . described as an L-shaped curve.

Dean offered a similar rationale for his finding of the horizontal AVC or MC, actually three complementary “technical conditions of modern manufacturing”: a “wide range of choice in the machine hours used per week,” which thus “segment(s)” the plant; the short-run inability to substitute “fixed and variable input factors”; and the short-run inability to substitute “variable input factors for one another.” These “combine to cause marginal cost to remain constant over a wide range of output rate. . . .” (1976, 32–35). Dean attempted to resuscitate the upward rising supply curve (*MC*) by appeal to diminishing returns to advertising.¹⁸

Several alternative assumptions modify somewhat the shapes of these curves. First, if the wage structure embodies a shift differential, so that the second-shift wage rate exceeds the first-shift wage rate, and the third-shift rate exceeds the second’s, then *MC* becomes a step function with the steps occurring at the weekly outputs associated with the shifts. A more complicated step function can also reflect overtime wage rates.

Second, the expansion path *Oh* (or OH_3) might exhibit increasing or decreasing returns, rather than constant returns. This is a form of short-run returns to the operation of the plant, not returns to scale and not increasing or diminishing marginal productivity. If the underlying production function exhibits decreasing returns along the short-run expansion path *Oh*, then *AVC* and *MC* are upward rising. A falling *AVC* results from increasing returns along *Oh*.¹⁹



CONCLUDING REMARKS

This reformulation of basic short-run production functions and cost curves is tantamount to denying the industrial reality of diminishing returns and the law of variable proportions. Interpreting capital in short-run production functions strictly as a flow of capital services rather than as a stock (as marginal productivity and partial derivatives require) allows the theory to reflect both the “damned facts” of AVC horizontality and fixed factor proportions. The result is the replacement of smoothly rising AVC and MC by Kahn’s — shape.

If the standard U-shaped unit cost curves are replaced by a horizontal AVC that goes vertical at capacity, what happens to our description of a competitive firm’s profit maximizing choice of a rate of output? Price-taking behavior, the standard assumption for firms in competitive product markets, suggests that a firm will produce either at capacity (where AVC goes vertical) for $P > AVC = MC$, or 0 for $P < AVC = MC$. If $P = AVC = MC$, then output is indeterminate.

But we observe that most firms most of the time produce outputs *between* 0 output and capacity output. A determinate solution in this range would require a negatively sloped demand curve, so that a firm’s Q and P may correspond with the equality of the negatively sloped MR and the horizontal MC .²⁰ This prospect raises the problem of monopoly (including monopolistic competition) smack in the middle of discussions of competitive general equilibrium.²¹ But the necessity to invoke monopoly (price-setting) behavior challenges the logical coherence and beauty of our crown intellectual jewel.

If our pedagogic goal is to describe a firm’s cost curves with reasonable accuracy, then this argument—short-run fixed-factor proportions—is relevant. If our pedagogic goal is to describe perfectly competitive general equilibrium—the circular flow, then we need short-run MC with a positive slope, that is, diminishing returns to labor, and this argument becomes an endnote along with the exceptions of monopoly, externalities, public goods, and incomplete markets.

NOTES

1. “Diminishing returns,” the eventually diminishing marginal physical productivity of a variable factor applied to a fixed factor, is distinct from diseconomies of scale, also occasionally termed diminishing returns.
2. How did we jump from diminishing returns in 19th century agriculture to diminishing returns in 20th century manufacturing? Likely the explanation rests on economists’ discovery and use of multivariable calculus, especially J. B. Clark’s 1899 use of partial derivatives (marginal products) to explain factor shares and to contribute to the “solution” of the adding up problem, and Jacob Viner’s exposition of the long-run LAC envelope (Viner 1931).
3. Diminishing marginal productivity of a variable factor (other factors held constant) requires the “law of variable proportions,” the ability to apply more or less of a variable factor to a given quantity of the fixed factor. Neither this nor the law of (eventually) diminishing (marginal physical) returns should be termed a law.
4. This was true for the introductory textbooks I sampled; I quit the survey at 18 books. The group included the current editions of some incumbent best sellers as well as three new entrants. My survey of intermediate textbooks was less thorough but provided no contrary evidence. Often the reason given for diminishing returns involves a smaller capital-labor ratio with an increased labor input; as L increases, each laborer has less capital to work with, hence labor’s productivity declines.
5. The theoretical literature goes further. Stiglitz (1994, 27) summarizes thus: “. . .[T]he first fun-

damental theorem of welfare economics—asserting the efficiency of competitive economies—is fundamentally flawed,” as is the second theorem, that issues of efficiency and distribution can be separated, largely because of imperfect information and incomplete markets.

6. To derive the marginal product of the variable factor labor, Robertson had to hold capital constant as labor varied. To do that, he held constant the amount or quantity of capital, what Joan Robinson called “leets,” but (with J. B. Clark [1899]) he appealed to “the principal of the variability of the *forms* of the [fixed] factors of production” (Robertson 1931, 227). Hence the “cheaper spades.” This means that Robertson had a short-run problem in mind. Altering the “form” of capital as labor varied was an intellectual device to keep capital (amount) constant. The lump of leets capital could be squeezed or spread out to accommodate less or more labor (Robinson 1970, 311–13).
7. Readers are invited to inspect their favorite introductory and intermediate micro textbooks to see if the authors distinguish capital stocks and capital flows. Many display a disturbing carelessness, often by labeling the fixed factor (on the y axis of the graphical production function) capital. Even output frequently lacks the time dimension to suggest its flow nature. Fortunately, much empirical work has been carefully done and does not confuse stocks and flows (e.g., Beaulieu and Matthey 1998, and references therein; Bresnahan and Ramey 1994; Aizcorbe 1992); Bertin, Bresnahan, and Roff 1996; Das 1992; Marris 1964. Of course, the time dimension must be the same for all variables in the production function: output per week, man hours per week, machine (capital) hours per week. What time dimension is appropriate (day, week, month) may depend on the circumstances, that is, the particular industrial problem.
8. Of course, machines may be speeded up or slowed, and workers may exert more or less effort; these are ignored or assumed away by the standard assumptions of homogeneous labor services and homogeneous capital services.
9. About 10 years ago, a research group at Princeton, headed by Alan Blinder, interviewed executives in 200 U.S. firms concerning their pricing policies. The 190 responses to the question on the behavior of their respective “variable costs of producing additional units as production rises” produced the following results: “only 11 percent of GDP is produced under conditions of rising marginal cost. Almost half [48.4%] is produced under constant MC But that leaves a stunning 40 percent of GDP in firms that report declining MC functions. . . .” (Blinder, Lebow, and Rudd 1998, 102, 103, 216–18).
10. Beaulieu and Matthey (1998) measure the flow of capital services by measuring the workweek of capital as part of their continuing study of capacity utilization. They distinguish capital utilization and capacity utilization, and they present an admirable survey of the empirical literature.
11. Bresnahan and Ramey (1994) address the various margins of short-run adjustments and Aizcorbe (1992) addresses the procyclical nature of labor productivity. Neither directly addresses the issue raised in this article.
12. Some short-run adjustment is accomplished by a reduction in the raw material input. Of course, the two input (K, L) production function represents production functions with more inputs, for example, raw materials and, electricity. Labor as the variable factor is shorthand for labor-raw materials-electricity (and any other variable factor), all used in fixed proportions but applied in variable proportions to the fixed factor, capital. This is conceptually identical to Ricardo’s use of labor-seed-fertilizer (in fixed proportions) as the variable factor applied to land. More than two factors are an unnecessary complication.
13. The reader may note some similarities here to the Cambridge Controversy of the 1960s. Among other issues, those disagreements involved the relevance of neoclassical production and distribution theories. The controversy basically involved shifts in capital-labor ratios in response to changes in relative factor prices—the reswitching possibility or “Ruth Cohen Curiosum.” That is long run; my concerns are for the short-run appraisal of “the facts of life” (Samuelson 1966). Theory aside, as Ferguson (1969, 258) notes in his discussion of this controversy, “The crucial point to emphasize is that the validity of the neoclassical theory is an *empirical*, not a *theoretical*, question” (emphasis in original). These comments are offered in that spirit. During the Cambridge Controversy, Joan Robinson asked, “When you define the marginal product of labor, what do you keep constant?” Samuelson’s answer as reported by Robinson: “Either the physical inputs other than labor . . . , or the rate of profit on capital. . . .” (1970, 310), which Robinson found satisfactory. My answer: neither, if capital and labor inputs are interpreted as flows (as they should be) and if fixed proportions hold in the short run (as they do). Johansen (1959) asserts short-run fixed-factor proportions in his discussion of growth models, which reflect the putty-clay attribute of capital in the growth models of the 1960s. He provided no empirical support for this assumption of short-run fixed proportions.
14. Marris (1964, 5) correctly “restate[s] the production function by saying that annual output now

- depends on three variables instead of two: instantaneous [labor] employment, quantity of capital, and the rate of [capital] utilization." Marris's "quantity of capital" identifies the end point of the expansion path, or full capacity output, which is point h on the expansion path OH_3 . Lavoie (1992, 118–30) argues that AVC is generally horizontal, noting the empirical support for the horizontability and discussing the availability of unused capacity.
15. One can combine two technologies by linear segments connecting the teeth points, if the capital-labor ratio is otherwise not continuously variable, as is implied by the smooth long-run isoquants.
 16. This assumes that there is no market for the rental of capital services.
 17. Some, perhaps most, assembly plants are built to operate at a standard 40 hour (5 day, 8-hour shift) workweek. Higher labor costs (shift differentials) and inferior labor for second and third shifts likely contribute to this long-run capital budgeting decision.
 18. Larson (1991) dubs the difference between the theoretical U-shaped AVC and the empirical horizontal AVC a "dilemma." Inconsistency might be a better term. His solution retains variable factor proportions in the short run and develops a horizontal AVC from a short-run expansion path based on the ridge line in production space, where $MPL_L = 0$. Maxwell (1965, 1969) has a similar solution. Stigler's (1939) taxonomy of shapes for AVC and other unit cost curves rests on adaptability (variable proportions of variable to fixed factors) and divisibility ("wherever there are a large number of identical machines in a plant" [p. 308]). His cost curves do not reflect the flow nature of factor services. Marshall (1952, 311) had it right: "For short periods the stock of appliances of production [fixed capital] are practically fixed, but their employment varies with demand" (a marginal note). In the text: a high price of the product causes managers "to bring into active work all their appliances of production, and to work them full time and perhaps overtime. . . . The immediate effect of the expectation of low [product] price is to throw many appliances for production out of work, and slacken the work of others. . . ." Diminishing returns and hence an upward rising short-run supply schedule come in Marshall not from diminishing marginal productivity (variable proportions) but from inferior capital and "inefficient labour (perhaps tired by working overtime)" being pressed into service to meet high demand.
 19. This modification allows the AVC to reflect the results reported in Blinder, Lebow, and Rudd (1998), as cited in endnote 9.
 20. Interestingly, diminishing returns and variable proportions are applicable in agriculture, an industry that also provides us with examples closest to perfectly competitive product markets.
 21. In the long run in perfect competition and with no economies or diseconomies of scale, the number and size distribution of firms are indeterminate. The argument here adds a second, short run indeterminacy: horizontal AVC and MC and competitive price-taking behavior do not produce a determinate rate of output for a firm save at zero or full capacity. Hall (1986) has measured (micro) marginal costs from macro fluctuations for the U.S. economy. He concludes that a typical firm operates on "a decreasing portion of its average [total] cost curve," and that "an industry achieves its equilibrium along a flat portion of the [short run] marginal cost curves of its firms" (Hall 1986, 286, 314). His results—market power, no economic profit, flat marginal cost—point to monopolistic competition as the prevailing market structure. Macroeconomic theory increasingly relies on the micro foundation of monopolistic competition (Solow 1998).

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