Post Keynesian view of average direct costs: a critical evaluation of the theory and the empirical evidence

Today the accepted view among post-Keynesian economists, based both on the empirical evidence available on the subject and on the theoretical implications of assuming fixed technical coefficients in the short run, is that the firm actually faces constant prime or direct costs over the relevant range of output, with the zone of increasing costs lying to the right of that. (Eichner and Kregel, 1975, p. 1305)

The above quotation captures the kernel of the Post Keynesian view of the firm's average direct costs as it existed in 1975, and the view has remained substantially unchallenged and unchanged to the present day. On the other hand, most other aspects of Post Keynesian economics, such as monetary theory, theory of profits, theory of price determination and prices, and the theory of firm, have undergone a healthy and detailed critical analysis over this same period of time. Why this view has not undergone the same critical analysis can perhaps be explained by reference to the "vast" amount of empirical evidence supporting it and the "self-evident" nature of the theoretical explanation. The purpose of this paper is to reexamine the evidence and the theoretical explanation to see if they do in fact support the view that the firm's average direct costs are constant. Specifically the paper's first section will examine this view at the level of the plant, while the second section will examine the view which is evidenced when the firm uses more than one plant in production. The third section will conclude the paper.

The author is Assistant Professor in the Department of Economics, Roosevelt University. He would like to thank Alfred Eichner for comments on an earlier draft of this paper.
Before beginning, one needs to define direct costs and delineate its relationship to variable costs. Direct costs consists of the labor and materials directly used to produce the output. Variations in the flow rate of output generally mean that the usage of the direct inputs will vary; but this need not always be the case for individual inputs, especially labor inputs, as Zudak (1970) has clearly shown. Variable costs, on the other hand, consists of all those costs which vary as the flow rate of output varies. Since, as Dean (1976) has shown, overhead costs can vary as the flow rate of output varies, variable costs contains non-direct cost elements and hence cannot be considered the same as direct costs. In addition, it can also be concluded that incremental costs includes non-direct cost elements and thus cannot be used without careful inspection to predict the behavior of average direct costs.¹

Average direct costs at the level of the plant

To determine whether average direct costs (ADC) at the level of the plant behaves as Post Keynesian economists suggest it does, we must first outline these economists' theoretical explanation of its behavior. To start it must be noted that the explanation is a two dimensional comparative analysis of costs with respect to different flow rates of output; hence its frame of reference is a moment in economic time and one which corresponds to a definite length of calendar time. Consequently the explanation concentrates its attention on the “virtual” movement of costs and the flow rate and on the relationship between these two variables as if they were being considered isolated in a vacuum (Roncaglia, 1978, p. 21; Levine, 1981). As a result the material input prices and wage rates are fixed and the plant's productive structure is given.

Because Post Keynesians view capital equipment as fixed and assume fixed technical coefficients, variations in plant output can occur only if the plant's productive structure is segmented.² That is, let us call

¹Since incremental costs is also irrelevant for Post Keynesian theories of pricing, prices, and the firm, it will not be discussed in this paper. Moreover, because incremental costs cannot be used to predict the behavior of average direct costs, studies which deal only with incremental costs with no reference to average direct costs cannot be used to prove or disprove the constancy of average direct costs. Thus the well-known studies of Dean (1942) and Lyle (1957) will not be used in this paper.

²Dean (1941a, 1941b, 1951, 1976) was apparently the first economist to employ the concept of plant segment to explain the shape of the plant average direct costs (PADC) curve. The concept was later adopted by economists to deal with technical change and accumulation and was rechristened “best practice technique.”
the plant's primary unit of production a plant segment (PS), which is defined as the technical specifications of direct material and labor inputs needed to produce a unit of output in a specific period of time. This vector of direct inputs is, in turn, uniquely determined—given the plant—by the underlying capital equipment and the social/labor conditions surrounding production (Eichner, 1976, pp. 28–30). Moreover, the specific capital equipment used in production of the unit of output is uniquely related to it in that it is specifically tailored to produce a given amount of output per period of calendar time. The period of time used in the specification of the PS is called the production period and it denotes the amount of calendar time needed to produce the unit of output, starting with the first input and ending with the output. Therefore, given the capital equipment and their operating specifications, the unit of output, and the production period, the plant segment can be delineated in the following manner:

(1) plant segment (PS): \[ g = \sum_{i=1}^{n_z} a_i \times l_i \]

where \( a_i \) is a direct material technical coefficient; \( l_i \) is a direct labor technical coefficient; and \( g \) is the unit of output per production period.

Since each PS is a recipe of rigidly fixed ingredients for producing a single unit of output, it is impossible for any one PS to produce more than one unit of output per production period. Consequently, if the plant's flow rate of output is to increase, an additional PS complete with its specific complement of capital equipment must be engaged. Now assuming that each PS is identical and setting \( g \) equal to 1, we find that the plant's moment-in-economic-time response to increasing its flow rate of output can be represented as

(2) \[ q_m = \sum_{j=1}^{m} g_j - \sum_{j=1}^{m} \sum_{i=1}^{n_z} (a_i \times l_i)j \]

or

\[ q_m = q_m \sum_{i=1}^{n_z} (a_i \times l_i) \]

since \( q_m = mg = m \), where \( m \) is the number of plant segments used to produce the flow rate of output and \( q_m \) is the total number of units of
output produced per production period of the flow rate of output production period.

From equation (2), we can derive the average amount of direct material and labor inputs needed to produce a unit of output at a given flow rate of output by dividing by \( q_m \):

(3) average plant segment (APS):

\[
1 = \frac{q_m}{q_m} \sum_{i=1}^{n} \left( a_i \times l_i \right) = \sum_{i=1}^{n} \left( a_i \times l_i \right)
\]

where

\[
\sum_{j=1}^{m} \sum_{i=1}^{n} a_{ij} = a_i
\]

is the \( i \)-th average plant material production coefficient at \( q_m \) and

\[
\sum_{j=1}^{m} \sum_{v=1}^{s} l_{ij} = l_v
\]

is the \( v \)-th average plant labor production coefficient at \( q_m \).

The theoretical implications that can be derived from equation (3), while obvious, are significant for the Post Keynesian explanation of ADC. First of all, the average plant segment is the same as any particular plant segment. This in turn means that the average plant production coefficients are the same as the technical coefficients and, hence, do not vary with variations in plant output. The constancy of the labor production coefficients has, in fact, been assumed by Post Keynesians such as Harris (1974) and Asimakopulos (1975) as a way to explain the shape of the ADC curve they employ. The second implication is that the plant’s average direct costs (PADC), the plant’s average direct material costs (PADMC), and the plant’s average direct labor costs (PADLC) are constant. This can be easily seen by introducing input prices and wage rates to equation (3):

(4) \[
PADC = \frac{q_m}{q_m} \sum_{i=1}^{n} \sum_{v=1}^{s} \left( a_i p_i + l_v w_v \right) = \sum_{i=1}^{n} \sum_{v=1}^{s} \left( a_i p_i + l_v w_v \right)
\]
\[(4^*) \quad \text{PADMC} = \sum_{i=1}^{n} a_i p_i \]

\[(4^*) \quad \text{PADLC} = \sum_{s=1}^{s} l_s w_s \]

The above theoretical results associated with equations (3) and (4)--(4*) represent the essence of the Post Keynesian explanation of ADC at the level of the plant, which is supposedly well supported by empirical evidence. However, contrary to their claims, the empirical evidence—summarized in Table 1 and more fully discussed in the Appendix—does not support them. Rather, the statistical and engineering-based evidence suggests, for example, that PADC could be increasing, decreasing, or constant depending on the plant's structure of production. Interestingly enough in cases where PADC is constant (Dean, 1941b; Johnston, 1960; Koot and Walker, 1969-70) the "plant segments" were highly uniform, thus fulfilling the most necessary condition for this result to occur. On the other hand the non-constancy of PADLC and PADMC can also be directly linked to the nature of the plant's productive structure, as Zudak and Ferguson clearly showed.

These results strongly suggest that the Post Keynesian view of production at the level of the plant is in need of substantial revision and elaboration. That is, since the evidence indicates that the ADC curve is not necessarily horizontal, it must be concluded that the plant segment technical coefficients are not fixed, that the use of fixed technical coefficients is not an adequate basis on which to explain the shape of the ADC curve, or both. In fact if, as the evidence suggests, plant segments are not all identical as would be the case under incomplete intraplant diffusion of technology (e.g., see Hollander, 1965), the plant is not completely segmented, resulting in, say, labor inputs not being fully utilized at a specific flow rate of plant output, or if the technical nature of production requires the material technical or production coefficients to vary as the plant's flow rate output varies, then ADC, ADLC, and ADMC will cease to be constant. Thus we arrive at the inescapable conclusion that neither the Post Keynesian theoretical explanation of the shape of the ADC curve nor their claim concerning the empirical evidence can be sustained.

\[\text{It should be noted that for his cost studies Dean deliberately picked plants whose plant segments were relatively homogeneous. This was due to the fact that his cost studies were designed to test the neoclassical law of diminishing returns which assumes that the units of the variable inputs are homogeneous in quality. Thus Dean's results cannot be taken as universally valid (Dean, 1976, pp. 23 and 33).}\]
Table 1

Plant level cost studies

<table>
<thead>
<tr>
<th>Study</th>
<th>PADC</th>
<th>PADLC</th>
<th>PADMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kempner (1960)</td>
<td>Declines to 50-60%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nordin (1947)</td>
<td></td>
<td></td>
<td>Increasing</td>
</tr>
<tr>
<td>Johnston (1960)</td>
<td>Constant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferguson (1950, 1953)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bower (1964)</td>
<td>Declining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dean (1938)</td>
<td>U-shaped</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dean (1941a)</td>
<td>Increasing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dean (1941b)</td>
<td>Constant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Koot and Walker</td>
<td>Constant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1969-70)</td>
<td>increasing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Griffin (1972)</td>
<td>Constant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Davies (1983)</td>
<td>U-shaped</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hettens (1969)</td>
<td>Constant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fog (1960)</td>
<td>Constant (in 3 cases)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muir (1957-58)</td>
<td>Declining</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increasing (in 1 case)</td>
<td></td>
</tr>
</tbody>
</table>

Notes: PADC = plant average direct costs; PADLC = plant average direct labor costs; PADMC = plant average direct material costs.

Average direct costs and multi-plant production

Many large industrial and transportation firms employ more than one "plant" to produce a specific product output. Thus the number of plants actually used in production will depend on the flow rate of output at which the firm is producing and on the flow rate of output of each plant. Consequently the shape of the firm's average direct costs (FADC) curve—as opposed to the shape of the plant average direct costs curve—will depend on which plants are being utilized and the degree of utilization of each plant. To determine whether FADC behaves as Post Keynesians suggest it does, we must first fully develop the Post Keynesian explanation of its behavior. Following the lead of Eichner (1976) and Harcourt and Kenyon (1976), let us assume that
each plant is made up of identical plant segments and that each plant is fully utilized (or utilized at some specific flow rate of output). This ensures that variations in firm output will be affected only by the opening up or closing down of whole plants and that the total labor and material inputs for each plant and, hence, the plant's production coefficients will not be affected by variations in output. Thus each plant can be represented by:

\[ q^n_{mk} - \sum_{j=1}^{m} \sum_{i=1}^{n_x} (a_{ij} \times l_{ij}) \]

where \( q^n_{mk} \) represents the maximum flow rate of output of the \( k \)-th plant.

Since each plant can employ different kinds of labor and materials and produce different flow rates of output, it is not possible to determine the order in which the various plants will be used to produce the output without first comparing their average direct costs. This requires, however, a common unit of output since the unit of output of a plant segment in a particular plant is not necessarily the same as the unit of output of a plant segment in a different plant. The complications that arise in this case can be avoided if we assume that the unit of output is chosen independently of the plant segment. Thus in the case of the segmented plant \( g \) will represent a specific amount of output (such as, for example, ten tons of steel) while \( q_m \) will represent \( m \) times that amount (since \( q_m = mq_g \)). Consequently, the plant's average direct costs and production coefficients will be expressed in terms of the independently chosen unit of output. Once this is done and assuming that the plant with the lowest average direct costs will be used first and those with higher ADC will be used later, the FADC for any specific flow rate of output can be delineated as:

\[ FADC_k = \sum_{x=1}^{k} \frac{\sum_{j=1}^{m} \sum_{i=1}^{n_x} (a_{ij} + l_{ij})x}{q^*_k} \]

where \( PADC_1 \ldots PADC_k; q^*_k = q_{m1}^* + \ldots + q_{mk}^* \) is the firm's flow rate of output when \( k \) plants are employed;

\[ \sum_{x=1}^{k} \sum_{j=1}^{m} a_{ijx} \]

\[ q^*_k \]
is the firm's $i$-th material production coefficient; and

$$
\sum_{x=1}^{k} \sum_{j=1}^{m} \frac{l_{xjk}}{q_{jk}}
$$

is the firm's $\nu$-th labor production coefficient.

The implications that emerge from equation (6) concerning the behavior of FADC are threefold. First, if plants have different technology then their ADC is most likely to be different. For example, if one plant contains more up-to-date technology than another—as exhibited by comparatively lower input usage or usage of different and cheaper inputs—then its average direct costs will be lower. Secondly, since each plant can be seen as “best practice technique” or vintage “best practice technique,” the average direct costs of the most recently constructed plants will be lower than that of older plants. This is especially the case if the newer plants incorporate technological and organizational innovations which enable them to increase their scale of production and utilize very specialized equipment (Gold, 1981). Lastly, if the material and labor inputs for each plant differ in type and quantity due to differences in technology, then the firm’s production coefficients will vary as the firm’s flow rate of output varies, even though the plants’ production coefficients remain unchanged and the technical coefficients of the plant segments are fixed. In fact in this case the relationship between the firm’s production coefficients and changes in the firm’s flow rate of output cannot be specified a priori; rather it will depend on the kinds of technological and organizational innovations the firm has incorporated into its plants. If the plants' productive structures are identical in all respects, then changes in the firm’s flow rate of output will leave its production coefficients unchanged. However, if the plants are not all identical, then the firm’s production coefficients can increase, decrease, or even alternate directions with respect to changes in the firm’s flow rate of output (for further discussion, see Lee, 1983).

Taking the implications together, they clearly indicate that the only situation in which FADC will be constant is when all plants are

“Best practice technique” is generally viewed as a set of “incremental” production coefficients that differ from the average production coefficients and that are based on the most advanced technology as embodied in the underlying new plant and equipment. Such techniques are also viewed as having the lowest average direct costs. For further discussion see the Appendix, Part II, section D, and references cited within.
Table 2

Costs and multi-plant production

<table>
<thead>
<tr>
<th>Best practice technique</th>
<th>Economies of scale</th>
<th>Vintage multi-plant production</th>
<th>Intrafirm diffusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korniya and</td>
<td></td>
<td>Scherer (1975)</td>
<td></td>
</tr>
<tr>
<td>Takao (1963)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ozaki (1970)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forsell (1972)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

identical. In this case the firm's production coefficients will not change as its flow rate of output changes. In other words, plants are not identical for any reason, then the FADC will increase as the firm's flow rate of output increases because a plant with higher ADC will be brought on line to supply the additional output, and, correspondingly, the firm's production coefficients will vary as its flow rates of output vary.

The empirical evidence—as summarized in Table 2 and more fully discussed in the Appendix—supports the position that the firm's plants are not identical and, therefore, that its average direct costs increase as its flow rate of output increases. For example, the studies on intrafirm diffusion clearly show that a firm's plants are not technically identical at a point in time; rather, the diffusion of new technology among its plants generally takes a number of years. Moreover, the studies on best practice technique indicate that the production coefficients of the new plants are different (generally less) than the production coefficients of their vintage relatives. Finally, the vintage multi-plant production stud-

\[ g_k = \frac{1}{k} \sum_{i=1}^{n} (a_i q_i + l_w) = \frac{1}{n} \sum_{i=1}^{n} (a_i q_i) + l_w \]

for any flow rate of output.
ies show that firms use plants that were built in different years (and presumably incorporate different kinds of technology and organizational innovations) and, consequently, have different costs. In fact Hollander’s study explicitly showed that Du Pont employed plants which produced the same output but had different costs and that the plants with the more up-to-date technology had the lower ADC. These latter results are supported by the studies on economies of scale. Thus we must conclude that neither the Post Keynesian explanation of the shape of the FADC curve nor its claim concerning the empirical evidence can be sustained.

Conclusion

Given the above discussion, it is impossible to escape the conclusion that the Post Keynesian view of average direct costs cannot be sustained. However, some Post Keynesians may try to rescue it by stating that “no harm is done, and greater simplicity of exposition is obtained, if it is simply assumed. . . .” 6 To economists who routinely make assumptions that contradict the facts, such a route would be very enticing; however, it is hoped that such recourse will be left to Friedman and his methodological followers. Aside from ignoring the evidence, any attempt to rescue the view will in fact bring a great deal of harm to Post Keynesian economics, especially its theory of the firm. That is, if FADC and PADC are assumed to be constant, then the notions of intraplant and intrafirm diffusion of technology makes no sense. Moreover, the problems of partial and complete plant closings and the deindustrialization of a geographical region could, simply put, not be discussed at all. Finally, it would be impossible to acknowledge the historical existence of basing point pricing in the steel or cement industries. In short, the assumption restricts the Post Keynesian theory of the firm to an imaginary economy where nothing happens and nothing changes.

The abandonment of this view, on the other hand, frees Post Keynesian economics from at least one shackle it inherited from the past while at the same time opening up new areas for investigation. Once it is admitted that the PADC curve can have any shape—depending on the

6Eichner (1976, p. 35) makes this statement after an excellent discussion of average direct costs and multi-plant production. Why he chose to depreciate his own progressive analysis of costs is unclear since the assumption is not needed in any way to carry out his analysis of pricing and prices (see Lee, forthcoming).
physical laws, engineering relationships, the social design incorporated into a plant’s productive structure, and the efficiency of the plant segments—it becomes impossible to view the curve as if it were based on a natural law. Thus it now becomes possible to investigate how a firm alters its ADC curve through altering its PADC curves. More importantly, it becomes necessary to develop a more comprehensive view of production and costs which includes both the perfectly segmented approach discussed above and the partially segmented approach and which incorporates time in a meaningful manner. This last point is significant since the empirical evidence suggests that plant average direct costs curves are to some degree irreversible (see Dean, 1936, 1976; Gold, 1971) and theoretical investigations into production suggest that the organization of production cannot be adequately understood if time is ignored (Scanzieri, 1983).

The abandonment of the view also opens up another, possibly unexpected, area for investigation. When working with industry level input-output models many Post Keynesians employ the assumption of constant returns to scale with respect to the relationship between industry production coefficients and the industry’s flow rate of output. Given the above analysis, the assumption clearly implies that the firms in each of the industries employ technically identical perfectly segmented plants. In other words, the assumption is a short-hand way of stating that technical progress has not occurred in the present history of the economy, the industries, or the firms. But such an economy is not only imaginary, but it is also, I suggest, incommensurable with capitalism and the capitalist firm. Thus it does not appear that Post Keynesians can assume constant returns to scale and say anything meaningful about the workings of capitalism and the capitalist firm. The veracity of the conclusion may be doubted, but the importance of the theoretical problem it poses cannot be, once the view of constant ADC is discarded.

Without the view of constant average direct costs, Post Keynesian “micro” theories will certainly become more complex. But is theoretical complexity necessarily bad? Perhaps Post Keynesians have hid behind their simplistic parables of pricing, prices, and the firm too long. This paper suggests so and asserts that the result has been detri-

*Since the notion of scarce factor inputs and the law of diminishing returns is not used in the above analysis of average direct costs and, moreover, since it is not possible to maintain a clear notion of fixed-in-quantity inputs when variable inputs are “applied” to them when working with a segmented approach to production and costs, any theory of average direct costs developed along the lines suggested above will be completely different from the neoclassical theory of (variable) costs.
mental to the development of Post Keynesian economic theory. The paper also suggests this situation need not, and indeed cannot, continue into the future.

APPENDIX

Cost studies relevant to understanding the firm's cost structure

I. Plant level cost studies

   a. Type of firm investigated—launderette shops.
   b. Firm's structure of production—one shop had 8 washers and another had 15 washers (with accompanying dryers). The period of production under consideration is a 49-hour week. Output consists of washers—the maximum number for the 8-washer shop is 578 and for the 15-washer shop 1,100.
   c. Costs:
      (1) Fixed costs included depreciation, recurring fixed costs such as rent, rates, supervision, and accounting, and fixed wage costs since the 8-washer shop needs one full-time and one part-time attendant and the 15-washer shop needs two full-time attendants.
      (2) Direct costs (or variable costs) included fuel, electricity, water, soap, and softening salts.
   d. Shape of the cost curves:
      (1) Average direct costs curve—declines to 50 to 60 percent of capacity and then is constant.
      (2) Average fixed costs curve—declines continually.
      (3) Average total costs curve—declines continually.
   e. Explanation for the shape of the curves:
      The shape of the ADC curve results from fuel costs declining as output increases.

   a. Electric light and power plant.
   b. The output, electricity, was produced by a single turbo-alternator and two similar boilers; the period of production was an 8-hour shift.
   c. The only cost of interest was fuel cost, which varied with the level of output (it appears that fuel cost was the plant's only direct cost).
   d. Average direct (material) costs increased as the level of output increased.
   e. No explanation was given.
   b. Output consisted of 14 separable, identified kinds of products, each of which was produced by processes which were quite similar, by an essentially homogeneous labor force, and by similar machines. Consequently, variations in output of any one product could be matched by the opposite variation in other products, especially the "filler products" (which also happen to be storable, unlike the other products).
   c. (1) Overhead costs—indirect labor, salaries, factory charges, laboratory expenses, and so on.
      (2) Direct costs—materials, labor, packing, and freight.
   d. Average direct costs curve—it was not explicitly derived, but since the incremental costs curve was found to be horizontal over the observed range of output, it can be concluded that the ADC curve behaves in the same manner.
   e. No direct explanation, but one can be deduced from the description of production found in (b) above.

   a. Manufacturing firm which produces plastic containers.
   b. Output consists of 10 different plastic containers; structure of production was not discussed, but indirect evidence (based on the non-existence of cost interrelationships as in Johnston’s analysis) indicates that the production processes could be quite similar. The period of production was monthly.
   c. Only direct costs were dealt with and these included labor, materials, and machinery (this inclusion was not explained).
   d. Average direct costs curve—horizontal over the range of output.
   e. None.

   a. Steel plant.
   b. Output consists of steel; the structure of production consists of 7 furnaces of differing efficiencies, with the most efficient being used first. The production period is a 24-hour day and a 7-day week; if a furnace is started up at the beginning of the week, it remains in production for the entire week. A standard work crew varies with the number of furnaces in operation but does not increase in a constant amount as the number of furnaces utilized increases.
   c. Deals only with direct labor costs.
d. Average direct labor costs curve—it is not derived directly; however, Zudak showed that the incremental labor costs curve was saw-tooth shaped, thus implying that the ADLC curve is not horizontal.

e. The non-horizontal ADC curve occurs because the standard crew does not vary proportionately with the number of furnaces in operation.

   b. Production is considered only in terms of a particular department called the pickle. Output consists of 5 different steel products; the plant productive structure consists of different kinds of machines which can be used to make some products but not others; crews are assigned to work certain machines and to produce certain kinds of output; because the different outputs are interrelated, the labor (and machines) are not usually fully employed.
   c. Considers only direct labor costs.
   d. Average direct labor costs curve—slopes downward.
   e. Due to the nature of production described in (b) above.

   a. Airline firm (Northeast Airlines).
   b. The costs being dealt with are fuel costs; thus the structure of production is presented in terms of an engineering formula. Output is measured in gross foot-pounds produced per month. The production unit producing the output is an airplane.
   c. Only direct fuel costs are dealt with.
   d. Average direct material costs curve—it was not derived directly, but Ferguson did derive the incremental material costs curve and it sloped upward as output increased, thus implying that the ADMC curve slopes upward.
   e. Given in terms of the engineering formula.

   a. Brick/clay refractory plant.
   b. Manufacturing cycle is 2 weeks; 60 percent of the labor is involved in handling material; the process is continuous, and though all steps are not on the same work schedule each step is dependent on the one which precedes it. Because the steps are not on the same work schedule, the drying and burning facilities set the output limit in the short period. The continuous nature of the process forces plants to use a large proportion of the normal labor force in order to operate at
all. The result is that the same quantity of labor (or other direct inputs) required to produce 1 percent of capacity output will also be able to operate the plant at 25 to 30 percent of capacity.

c. Costs were divided into fixed non-operating costs, fixed operating costs, and direct (variable operating) costs.

d. (1) Engineering estimate:
   (i) Average direct costs curve—declines
   (ii) Average total costs curve—declines up to full capacity.

(2) Empirical cost study (of a clay refractory plant which is very similar to the brick plant):
   (i) Average direct costs curve—declines since Bower showed that the incremental costs curve declined.

c. The tendency for average direct costs to decline as output expands seems to be explained by the production plan. Successive additions to output permit workers more specialization, less intraplant movement, and the opportunity to perform more carefully tasks which are essentially indivisible. This will be the case for almost the entire production range or until kiln limitations make further additions to output impossible.


a. Furniture factory:
   (1) Structure of production—the factory consisted of 2 plants which produced the same products and were substantially alike in degree of mechanization and in methods of organization. They were operated as one unit. The production period was a 2-week accounting period. Output was measured by old warehouse value (this is a composite commodity based on the standard cost for each separate model of furniture).

   (2) Costs were divided into direct and overhead costs.

   (3) (i) Average direct costs curve—U-shaped.
   (ii) Average direct labor costs curve—declines.
   (iii) Average direct material costs curve—U-shaped.

   (4) The shapes of the curves were not explained, except that the U-shape emerges because of material waste increases as the level of output increases.

b. Hosiery mill:
   (1) The period of production is a month and output is measured in terms of a dozen stockings. Production is highly mechanized and employs skilled labor. Production is also highly segmented in that production is carried out on identical machines so that variations in output result in variations of the number of machines in use.
(2) Costs were divided into direct labor costs, mill overhead costs, and general (or firm) overhead costs. Direct material costs were ignored (but Dean inferred that average direct material costs were constant). Because of the segmented nature of production the mill overhead costs were not fixed with respect to variations in output. In fact Dean's study clearly shows that fixed and variable costs are not the same as direct and overhead costs.

(3) (i) Average direct costs curve—increasing (since average direct material costs are assumed to be constant).
(ii) Average direct labor costs curve—increasing.
(iii) Average total costs curve—declining.

(4) No explanation is given; however, it could be inferred that the shape of the direct costs curves is due to different efficiency in labor—but Dean does not discuss this.

c. Leather belt shop:
(1) Period of production is a month; output is measured in square feet of single-ply belting. Production is segmented into a number of similar operating units, each of which can be withdrawn from operation without influencing the efficiency of others.

(2) Costs are divided into direct and overhead costs. Overhead costs are not constant as output increases.

(3) (i) Average direct costs curve—horizontal.
(ii) Average direct materials cost curve—horizontal.
(iii) Average direct labor costs curve—horizontal.
(iv) Average total costs curve—declining.

(4) The shape of the direct costs curves comes about because of the highly segmented nature of production and the homogeneity of each segment and of the labor force.

   a. Petroleum refinery.
   b. See (e) below.
   c. Costs are divided into variable and fixed costs.
   d. The average variable (direct) costs curve slopes upward because Griffin showed that the incremental costs curve sloped upward.
   e. The upward sloping average variable (costs) curve can be traced to limited capacities of the 12 major process units. When a particular process unit reaches capacity, larger outputs can still be produced through substitution between processes. But such substitution involves cost. For example, in making gasoline, the catalytic cracking unit operates most efficiently on light gas oils but can process a much heavier feedstock called light vacuum tower bottoms. The older thermal crackers can operate only on the light gas oils. Once capacity
is reached in the catalytic cracker, the thermal crackers are then used
to process the light gas oil feed. The catalytic cracker must then be
used to process almost entirely the light vacuum tower bottoms. Since
light gas oils are processed by the more expensive thermal cracking
units, average variable (direct) costs increase.

   a. Individual container vessel.
   b. Production is the shipping of goods in containers. The production
      period is the length of time of going from one port to another.
   c. Costs are divided into variable and fixed costs. The variable costs is
      closely akin to the concept of direct costs since it consists of the
      commissions paid to agents for the soliciting of cargo and of the
      actual costs associated with handling, loading, and stowing the car-
      go.
   d. (i) Average total costs curve—declining.
      (ii) Average variable (direct) costs curve—horizontal.
   e. No explanation.

   a. Individual tanker.
   b. Production consists of shipping oil.
   c. Costs are divided into variable and fixed costs. Variable costs con-
      sists of vessel and voyage and loading expenses; thus variable costs is
      closely related to direct costs.
   d. (i) Average variable (direct) costs curve—U-shaped.
      (ii) Average total costs curve—U-shaped.
   e. No explanation.

   a. The study deals with 5 manufacturing firms which appear to be single
      plant firms.
   b. No discussion.
   c. Deals with direct material and labor costs.
   d. (i) Brushes firm: average direct costs curve—horizontal.
      (ii) Rope firm: average direct costs curve—horizontal.
      (iii) Manufacturer: average direct costs curve—horizontal.
      (iv) Clothes firm: average direct costs curve—increasing because
           the waste of material and the consumption of needles increased
           rapidly when output increased.
   e. No discussion.
   a. Boiler-house in a plant.
   b. The output is steam; period of production is 4 weeks.
   c. Deals with direct material, labor, and service costs.
   d. (i) Average direct costs curve—declining, but with the rate of decline falling as output increases.
   (ii) Average direct labor costs curve—declining.
   (iii) Average direct material costs curve—declining, but with the rate of decline falling significantly as output increases.
   e. No explanation given.

II. Costs and multi-plant production

A. Economies of scale

   a. Kinds of plants or parts of plants covered:
      (1) "Black liquor" evaporation in sulphate paper mills.
      (2) Electrolytic evaporator for sodium hydroxide.
      (3) Low temperature vacuum dehydration.
      (4) Petroleum refining.
      (5) Spin bath evaporation for rayon mills.
      (6) Steel.
      (7) Tonnage oxygen.
   b. Results—the larger the mill or plant in terms of output, the lower the direct labor, power, fuel, and heat inputs used in producing a unit of the output. This implies that average direct costs of different sized plants are different.
   c. Explanation—engineering explanation based on the "sixth-tenth rule."

2. Fratten (1971).
   This well-known study clearly shows that in the industries studied different sized (measured in terms of output) plants will have different average total direct costs with the larger sized plants having the lower costs. Thus this study implies that if a firm operates two different sized plants, its "overall" average direct costs curve will not be horizontal but rather will be upward sloping.

B. Vintage multi-plant production

a. The book contains data showing multi-plant production for a variety of steel products for various firms. The plants are dated as to when first constructed and updated. No cost data are given.
b. Examples of vintage plants or mills:
   (1) Plate producers, sheared carbon, and low alloy.
      (a) Bethlehem Steel: 3 plants—one built in 1955 and the others in 1964.
      (b) U.S. Steel Corp.: 6 plants—dates built are 1900s, 1930s, 1931, 1942, 1958, and 1974.
   (2) Cold strip mills producing strip wider than 26 inches.
      (a) Jones and Laughlin Steel: 8 mills—dates built range from 1945 to 1964.
      (b) National Steel Corp.: 13 mills—dates built range from 1935 to 1965.
c. Examples of specific vintage technology:
   (1) Basic oxygen furnaces:
      (a) Republic Steel Corp.: 5 furnaces—built between 1965 and 1977.
      (b) U.S. Steel Corp.: 5 furnaces—built between 1963 and 1972.
   (2) Electric arc furnaces:
      (a) Babcock and Wilcox Co.: 9 furnaces—built between 1941 and 1967.
      (b) Bethlehem Steel Corp.: 8 furnaces—built between 1938 and 1981.
   (3) Coke ovens:
      (a) Republic Steel Corp.: the ones in operation were built between 1943 and 1979.
      (b) U.S. Steel Corp.: the ones in operation were built between 1943 and 1978.
d. The data clearly show that steel firms employ different vintages (dated) technology and plants to produce their products. Although no cost data are available, it can be stated that average total and average direct costs can differ from one plant to the next, thus preventing the average direct costs curve for the firm from being horizontal.

   a. This study shows that plants built at different times embody different technology, that technology differences are the basis for differences between average direct costs and average factory costs in the technologically different plants, and that firms will continue to use plants which have different costs for a long time.
   b. Plants compared:
(1) Textile-yarn plants:

<table>
<thead>
<tr>
<th>Plant-year</th>
<th>Standard average direct costs</th>
<th>Standard average factory costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(in cents per pound)</td>
<td></td>
</tr>
<tr>
<td>1937</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spruance I</td>
<td>26.56</td>
<td>29.35</td>
</tr>
<tr>
<td>Spruance II</td>
<td>17.02</td>
<td>18.48</td>
</tr>
<tr>
<td>Old Hickory</td>
<td>17.69</td>
<td>20.12</td>
</tr>
<tr>
<td>1950</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spruance I</td>
<td>15.09</td>
<td>17.09</td>
</tr>
<tr>
<td>Spruance II</td>
<td>13.28</td>
<td>15.19</td>
</tr>
<tr>
<td>Old Hickory</td>
<td>13.37</td>
<td>15.29</td>
</tr>
</tbody>
</table>

(2) Tire-cord plants:

<table>
<thead>
<tr>
<th>Plant-year</th>
<th>Standard average direct costs</th>
<th>Standard average factory costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1945</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spruance IIA</td>
<td>11.97</td>
<td>12.86</td>
</tr>
<tr>
<td>Spruance III</td>
<td>11.03</td>
<td>11.68</td>
</tr>
<tr>
<td>1950</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spruance IIA</td>
<td>10.3</td>
<td>10.91</td>
</tr>
<tr>
<td>Spruance III</td>
<td>10.26</td>
<td>10.72</td>
</tr>
</tbody>
</table>

   The study shows that different cost plants producing the same output coexist and that (although not very clearly, but implicitly) different cost plants producing the same output coexist in the same firm.

   a. The study shows that the larger a tanker is, the smaller is its average variable cost per ton shipped.
   b. The study also suggests that if a shipper used different sized tankers, then its average variable costs would increase as its capacity utilization increased because it had to use the smaller tankers.

   a. The study indicates that firms in the titanium dioxide industry simultaneously use different processes which have different costs to produce titanium dioxide.
   a. Scherer states that some multi-plant firms vary their output by varying
      the number of plants in operation, with the least costly plants
      being used first. He states that certain cement manufacturers claimed
      an advantage in being able to run their most efficient works at full
      capacity and let the burden of demand adjustment fall upon high-cost
      works. He also stated that a brewing company claimed similar advan-
      tages.

C. Vintage plants and intrafirm diffusion of technology

   a. The study shows the average number of years from the time when 10
      percent of a firm's new machine tool purchases were numerical
      controlled machines to the time when 60 percent were numerical
      controlled machines. See the accompanying tabulation.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft engines</td>
<td>6.1</td>
</tr>
<tr>
<td>Airframe</td>
<td>4.3</td>
</tr>
<tr>
<td>Printing presses</td>
<td>3.1</td>
</tr>
<tr>
<td>Coal mining machinery</td>
<td>2.8</td>
</tr>
<tr>
<td>Digital computers</td>
<td>3.9</td>
</tr>
<tr>
<td>Large steam turbines</td>
<td>4.8</td>
</tr>
<tr>
<td>Machine tools</td>
<td>3.6</td>
</tr>
<tr>
<td>Farm machinery</td>
<td>6.5</td>
</tr>
<tr>
<td>Tool and die</td>
<td>3.5</td>
</tr>
<tr>
<td>Industrial instruments</td>
<td>2.3</td>
</tr>
</tbody>
</table>

   a. The studies included in the book clearly show that intrafirm diffusion
      of industrial processes takes place, thus implying that a firm's plants
      are not technologically homogeneous at any point in time. The indus-
      trial processes discussed in the book included numerical controlled
      machine tools, special presses in paper-making, tunnel kilns for
      brick-making, basic oxygen steel process, continuous casting of
      steel, application of gibberellic acid in malting, and shuttleless
      looms.

   a. The study dealt with the intrafirm diffusion of the diesel powered
      locomotive.
D. Best practice technique—differential plant technology derived from input-output analysis


   a. Best practice technique (BPT) is generally viewed as a set of incremental production coefficients which are different from the average production coefficients and which are based on the most advanced technology as embodied in the underlying new plant and equipment.
   b. BPT is also viewed as the lowest cost technique (although at times this is not clearly spelled out).
   c. Since BPT is predicated on technical change and diffusion of the new technology, the average production coefficients will change over time for any given level of output. However, it is also easy to see (but not spelled out clearly in the above studies) that at any point in time the average production coefficients can vary with respect to different levels of output because of the existence of BPT and vintage BPT.
   d. Most studies take place at the industry level, but the same kind of analysis can take place at the level of the firm and in particular at the level of producing a particular kind of product.

REFERENCES


Carter, A. P. "Incremental Flow Coefficients for a Dynamic Input-Output Model with


F.T.C. See U.S. Congress.


Harris, Donald J. "The Price Policy of Firms, the Level of Employment and Distribution of Income in the Short Run." Australian Economic Papers, 1974, 13, 144-131.


