June 15, 1988

ECONOMIC COMMENTARY

Federal Reserve Bank of Cleveland

Measuring the Unseen: A Primer on Capacity Utilization

by Paul W. Bauer and Mary E. Deily

Capacity-utilization measures can be useful in evaluating industry price pressures, investment, and war mobilization capabilities. In this first article of a two-part series, the authors define and examine some of these measures. The upcoming July 1 *Economic Commentary* uses the concepts to analyze two widely disseminated indexes of capacity utilization.

How much wood could a woodchuck chuck if a woodchuck could chuck wood?

According to several available measures, a large number of U.S. industries are now operating at historically high levels of capacity utilization. Many analysts believe that further increases in demand, fueled by continued growth and especially by the expansion in exports, could result in higher output prices. This is particularly a concern if firms hesitate to expand their capacity by investing in new plant and equipment.

As a result, there has been considerable interest in understanding what the terms "capacity" and "capacity utilization" mean when referring to firms and industries. Two basic types of measures exist. The engineering, or war mobilization, measure attempts to represent the maximum physical output that a plant can produce, and is probably closest to the layman's idea of capacity. But economists find that a better indicator of industry price pressure and future investment is one that incorporates changes in production costs as output increases.

In this *Economic Commentary,* we use a simple model of a single plant to illustrate these alternative definitions of capacity and capacity utilization and to examine their properties. In the upcoming issue, we use these concepts to analyze the capacity-utilization figures published by the Census Bureau and by the Federal Reserve.

The Basic Concepts

Economists use two cost concepts to clarify the problem any firm faces in deciding how much output to produce. The first cost concept is average, or unit, cost (AC), the total cost of production divided by the current level of output. The second concept is marginal cost (MC), the additional cost a firm incurs to produce one more unit of output. Since a firm is assumed to be working with a given amount of plant and equipment that cannot be varied in the short run, this extra cost arises only from the additional labor, materials, or energy required to expand production.[1]

Typical shapes of the average cost and marginal cost curves are plotted in chart 1.[2] As the rate of output increases, average total cost initially falls, since at low levels of production increasing the rate of output spreads overhead costs (the cost of fixed inputs) over more units. Marginal cost tends to be relatively flat across a broad range of outputs. At some point, as fixed inputs (such as machinery) begin to be used more and more intensively, marginal cost rises more steeply and eventually exceeds average cost. At this point (point A in chart 1), average cost starts to rise, in the same way that a baseball player's batting average will rise if he hits better than his average during a game.

ISSN 0428-1276

For example, suppose an airline wants to increase the number of miles it flies with its current number of planes. The airline can fly each plane faster, but doing so will increase the amount of fuel per mile that each plane uses. Thus, the cost of producing the extra miles will be greater than the current cost per mile.

Note that this cost increase is not caused by increases in the prices of the variable inputs (in this case, fuel). The increase occurs because more fuel per mile is necessary to produce extra miles when the airline is using the same number of planes. In sum, we can think of firms as able to expand production over some range in which the extra units will cost about the same. At some point, however, more-than-proportional increases in labor, materials, or energy will be required to increase output further, thus raising both marginal and average costs.

So far we have assumed that the firm is working with a fixed amount of capital, but over time the firm can vary this amount. If the airline, for instance, is able to add planes to its fleet quickly, it could increase the number of miles flown without increasing its average total cost. In terms of the cost curves discussed above, a change in the amount of fixed inputs the firm employs will move the firm onto an entirely new set of average total cost and marginal cost curves.

This process is illustrated in chart 2. When a firm adds capital, for instance, it moves to a new set of short-run cost curves (from AC1 and MC1 to AC2 and MC2), because the added capital allows it to produce greater amounts of output at lower cost. The set of all possible short-run cost curves traces out the long-run average cost curve (LRAC), which is the lowest unit cost the firm can attain at each level of output after it has adjusted *all* of its inputs.

■ An Economic Definition of Capacity Utilization

Economists generally define a plant's capacity as the output level at which average total cost is lowest (again, the point at which marginal cost intersects average cost). If capacity is measured in this way, a plant producing at point A on chart 1 is producing at 100 percent of its capacity. But as demand increases in the product market, and as firms respond to higher prices by increasing output, firms will begin to produce at levels above capacity in order to maximize profits.[3] Capacity-utilization figures greater than 100 percent would thus be associated with above-average profits and rising production costs. If firms expect demand to remain strong, then capacity-utilization figures greater than 100 percent will also be associated with increased incentive to invest, as firms attempt to move to a more favorable set of cost curves by increasing their capital stock.

In contrast to this cost-based measure of capacity, an engineering measure is the maximum output that may be produced, ignoring all cost changes, with the equipment in place. This output level would be at the extreme right side of chart 1, where the average and marginal costs rise sharply. Measured in this way, a plant's capacity is likely to be beyond the point at which the firm could produce profitably. In order to obtain an estimate of engineering capacity, the firm must thus evaluate its production capabilities at output levels with which it has little or no experience.

In addition, the potential for a given capacity-utilization rate to create output-price pressure would be difficult to evaluate because the distance between the minimum of the average total cost curve and engineering capacity would differ from industry to industry. This makes it hard to determine from a particular capacity-utilization rate whether firms in an industry have moved beyond the minimum of their average total cost. For the same reason, the engineering capacity concept would also be more difficult to use than the cost-based measure as an indicator of increases in future investment.

■ Toward Real-World Measurement

So far, measuring capacity as the minimum point of a firm's current average total cost curve appears quite reasonable. Any firm producing above capacity will experience rising costs and will have an incentive to invest. But even when using a cost-based concept to evaluate capacity-utilization implications, several complications arise.

First, a given level of capacity utilization will have different meanings depending on firms' expectations for the future. Operating above capacity is a good indicator of future investment only if the firm expects the current output price to stay the same or increase. Also, industries protected from import competition, for instance, might not expect this protection to continue in the long run, and thus might not invest.

Second, if firms can quickly adjust their fixed inputs, and if the long-run average cost is as pictured in chart 2, a high capacity-utilization rate does not necessarily imply the existence of output-price pressures. A firm that is able to adjust its capital quickly can moderate its cost increases by moving to a more favorable set of short-run curves. The faster a firm can adjust its fixed inputs, the more moderate will be the cost and price increases as the firm expands its production to meet rising demand.

Third, we have so far assumed that the firm can expand production without paying higher input prices for

CHART 1 SHORT-RUN COST CURVES

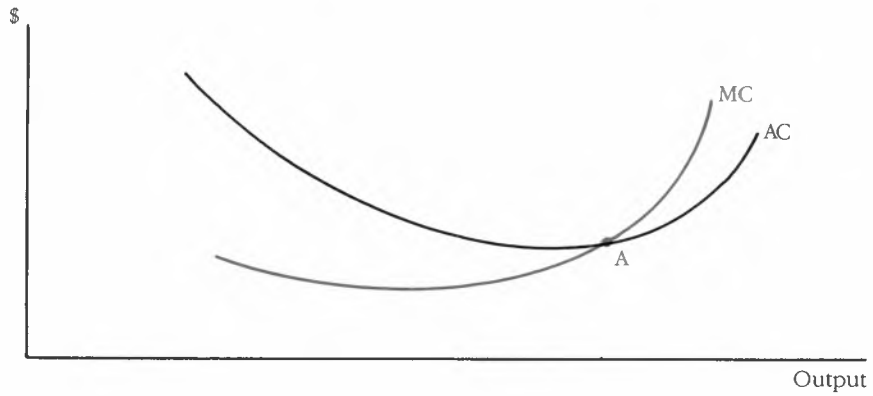
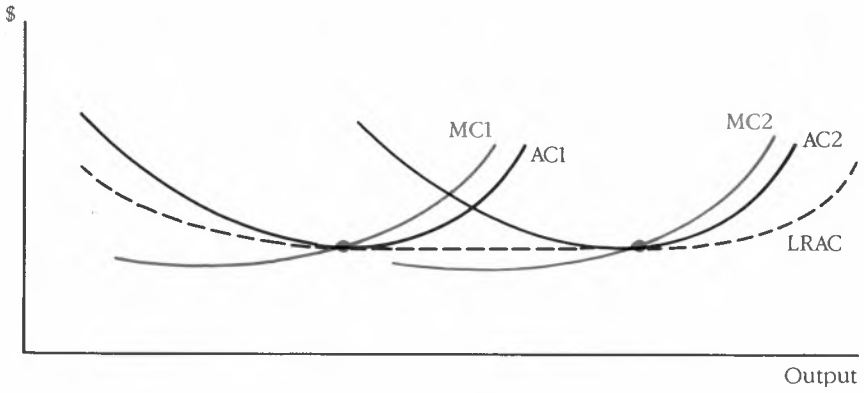


CHART 2 LONG-RUN COST CURVES



SOURCE: Authors' calculations.

additional labor, materials, or energy. But as all the firms in an industry respond to increased demand by expanding production, input prices may rise, particularly if the industry is a large purchaser of an input in limited supply.

An increase in input prices shifts all of the cost curves up, and firms might now reach minimum average cost at a different level of output. While firms might be producing at a level above their old capacity, they might be at or below their new capacity. In this situation, firms operating at or above a capacity measured at old factor prices may have less incentive to invest in new equipment, since rising factor prices reduce the profitability of additional investment.

■ Aggregate Capacity-Utilization Measures

Aggregate capacity-utilization figures must be interpreted carefully. As more sectors of the economy increase production, prices are likely to rise even for less-specialized inputs. Thus, high aggregate capacity utilization should at least be a good barometer of rising input prices, and thus of rising costs. But the relationship between aggregate measures and investment is less clear.

Furthermore, relationships between aggregate measures of capacity utilization, inflation, and investment may not be stable over time for at least three reasons. First, changes in government regulations or foreign supplies may abruptly alter an industry's capacity. Consider, for instance, the semiconductor agreement between the United States and Japan, which has significantly reduced the supply of some silicon chips, a vital input in computer manufacture. Production increases in this industry will consequently result in more rapid cost increases, as firms bid up the price of the available chips.

Second, changes in firm strategy may alter the relationships between capacity utilization, cost increases, and investment. For example, some firms now handle intermittent periods of very high demand by intensifying their use of the existing plant and equipment, rather than maintaining excess machinery that sits idle in periods of normal demand.

Third, aggregate measures reflect different compositions of utilization among industries. As shown above, high capacity-utilization measures in different industries have different implications for prices. Thus, the same numerical measure of aggregate capacity utilization may reflect different potentials for aggregate price pressure, depending on how quickly costs are rising in the industries with high utilization rates.

■ Conclusion

Capacity is fundamentally a cost concept most appropriately defined as the minimum point on the short-run average cost curve. In moving this clear, concise economic concept

closer to the real world, however, a number of potential interpretation problems are encountered.

While output prices will rise as firms produce beyond their capacity, the extent and persistence of the increase depends on the shape of industries' cost curves, on the sensitivity of factor prices to increases in demand, and on the willingness of firms to invest in new plant and equipment. In addition, changes in government regulation or in trade policy over time may increase (or possibly decrease) bottlenecks in the economy, limiting (or abetting) firms' ability to expand output without price increases.

Furthermore, this measure of capacity utilization will not have consistent implications for investment, as firms may be less inclined to purchase new equipment if they do not expect a permanent increase in the demand for their products, or if rising input prices reduce the profitability of new capital.

Because of these ambiguities, the potential inflationary pressure represented by any level of capacity utilization is unclear. Although measures of capacity utilization are informative, they contain conceptual difficulties. In the next *Economic Commentary* in this two-part series, we will discuss how the Census Bureau and the Federal Reserve construct their indexes of capacity utilization.

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The views stated herein are those of the authors and not necessarily those of the Federal Reserve Bank of Cleveland or of the Board of Governors of the Federal Reserve System.

Footnotes

1. Inputs that cannot be varied in the short run, such as machinery, are called fixed inputs, while those that can, such as materials or labor, are called variable inputs.

2. For summaries of the results of studies of industry cost curves, see Edwin Mansfield, *Microeconomics: Theory and Applications,* Fourth Edition, New York: W.W. Norton and Company, 1982, pp. 204-206; and Arthur A. Thompson, Jr., *Economics of the Firm: Theory and Practice,* Second Edition, Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1977, p. 285.

3. The firm increases production until the cost of producing additional units is greater than the price those additional units will bring, that is, until the level of output where unit price equals marginal cost is reached. Even if the cost of producing extra output is very high, net profits will still rise if the output price is even higher.

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