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Capacity Utilization

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The Federal Reserve Board publishes measures of capacity utilization for the U.S. industrial sector. The figures often are cited in discussions of inflation prospects, yet structural underpinnings for the relationship between capacity utilization and inflation are neither widely accepted nor generally understood. Moreover, some observers who accept the premise that high and rising levels of capacity utilization should signal inflationary pressures claim the Fed's estimates miss the true pattern of utilization. Others suggest that while a tight relationship between capacity utilization and inflation may have once existed, it has broken down more recently in an era of rapid technological change, increased international trade and a shift in the share of the nation's workforce to service-producing industries.

We believe that these concerns are exaggerated. In this article, we first review how the Federal Reserve defines and measures capacity utilization, addressing some of the persistent problems in measuring capacity utilization and spelling out how existing methods already incorporate many changes in economic structure, such as technological progress and trends in plant workperiods. We then further explain why capacity utilization has been and likely will remain a useful indicator of inflationary pressures and business cycle fluctuations. We also illustrate the microtheory that describes the concept of capacity utilization at the level of an individual producing establishment and review evidence on the plausibility of microeconomic structural interpretations of the relation between capacity utilization and price changes.

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What is Capacity Utilization?

Capacity utilization is a ratio of the actual level of output to a sustainable maximum level of output, or capacity. The Federal Reserve calculates measures of output, capacity and capacity utilization for the nation's industrial sector, which consists of industries within the manufacturing, mining, and electric and gas utilities subsectors. The output figures are monthly indexes of industrial production, and each industry utilization rate is equal to an output index divided by a related capacity index. The capacity indexes are designed to embody the concept of sustainable practical capacity, defined as the greatest level of output each plant in a given industry can maintain within the framework of a realistic work schedule, taking account of normal downtime and assuming sufficient availability of inputs to operate machinery and equipment in place. The concept generally conforms to that of a full-input point on a production function, with the qualification that capacity represents a realistically sustainable maximum level of output for a given industry, rather than some higher unsustainable short-term maximum.

Economists may debate about how capacity should be defined, but those who discuss production capability with plant managers quickly discover that managers generally are quite precise about how much their facilities can produce without extraordinary efforts.[1] The Federal Reserve's capacity statistics are grounded in survey evidence on utilization collected at the plant level for the fourth quarter of each year (for the most part). The questions asked in the Fed's source data generally conform to the concept of sustainable practical capacity described above, and the evidence reflects respondents' current assessment of the effect on utilization of structural changes, such as downsizing and the lengthening of the work week of capital, as well as the impact of innovations in processing technology. The Federal Reserve combines the available survey evidence on utilization with its industrial production indexes to obtain a consistent system of output, capacity and capacity utilization in regard to coverage, weights and other aspects of aggregation.[2]

Clearly, a persistent measurement issue for capacity utilization is the lack of comprehensive, high-frequency survey data on utilization rates. Thus, the true pattern of within-year variation in capacity utilization is unobserved. Because of the lack of monthly survey information on capacity, only annual capacity indexes are

[1] See the discussion of "pin factory visits" sponsored by the NBER Project on Industrial Technology and Productivity in the Spring 1996 issue of the *NBER Reporter*.

[2] In the industrial production (IP) index, series that measure the output of an individual industry are weighted according to their proportion in the total value added output of all industries. The IP index extends back to 1919 and is built in chronological segments that are linked together to form a continuous index expressed as a percentage of output in a comparison base year. The capacity indexes, which are similarly weighted, built and expressed, extend back to 1948 for manufacturing and to 1967 for total industry. Each segment of both indexes usually spans five years and is a Laspeyres quantity index showing changes in quantities with prices (Census value added per unit of output) held at base-year values for the segment. In a revision forthcoming in early 1997 and affecting data back to 1976, an annual chain-type formula will replace the Laspeyres formula for aggregating both the Federal Reserve's industrial production and capacity indexes; also, the comparison base year, currently 1987, will be shifted to 1992.

developed directly from basic source data. The annual results are interpolated to a monthly frequency. As a result, the Federal Reserve estimates of capacity generally follow an annual growth trend from roughly year-end to year-end, and short-term movements in utilization are dominated by changes in the production index, not the growth of capacity.

The actual capacity indexes have one more ingredient: they include information from alternative indicators of capacity change, such as growth of an industry's available capital input or, for selected industries, capacity measured in physical units. The actual capacity indexes are proportional to fitted values from regressions that reflect both the trend growth of capacity implied by the survey data (the growth of an industrial production index divided by a utilization rate from a survey) and the annual changes of the alternative indicator.[3] For the most part, timely and forward-looking estimates of the alternative indicators can be developed from data on business plans for investment and capacity expansion. As a result, extrapolations based on the same regressions, along with the production index, determine the Federal Reserve's capacity utilization rates since the latest survey observation. These initial utilization measures have proved highly consistent with the figures subsequently derived using survey data.

This basic method of capacity measurement remains much the same as originally introduced in the 1960s (deLeeuw, 1966), although it has been improved with time. Over the years, the system has been expanded from a few manufacturing series to about 75 series covering the entire industrial sector, and the definition of capacity has been made more explicit, along the lines of sustainable practical capacity as discussed earlier. Moreover, the quality of the survey source data has been raised. Originally, a survey conducted by McGraw-Hill/DRI was used, but in the 1970s, the Census Bureau initiated the *Survey of Plant Capacity*, which now provides more statistically valid source data for the Federal Reserve measures.[4] In recent years, more rigorous methods have been introduced for deriving the capital input measures used as annual indicators for most industries; the methods apply marginal-product weighting to Federal Reserve staff estimates of manufacturers' real net capital stocks.[5]

[3] Specifically, the regressions fit the logarithm of the ratio of the survey-implied capacity to the alternative capacity indicator by a low-order polynomial or piece-wise linear function of time. See Raddock (1990, 1996) for further details.

[4] Although the main survey used for manufacturing is the Census survey, for selected industries within manufacturing, private surveys with near or complete universe coverage of that industry also are used. For mining and utilities, the survey data are obtained from both government and private sources. The Census Bureau's capacity survey has collected responses from approximately 10,000 establishments drawn, on a probability basis, from the sample used for the Bureau's Annual Survey of Manufactures. (Benchmarks for manufacturing industrial production indexes also are derived from the Annual Survey of Manufactures.) For total manufacturing utilization, the resulting sampling standard error is about 1 percentage point. Forthcoming Census capacity surveys are designed for 14,000 responses and will result in a somewhat smaller sampling error.

[5] The capital input calculations follow standard practice, and the net stocks are Federal Reserve estimates derived by the perpetual inventory method from investment data. The Fed's manufacturing net capital

Shapiro (1989) questioned the Federal Reserve's estimates of capacity utilization on several grounds. A primary concern was the vagueness and open-ended nature of the McGraw-Hill/DRI survey questions about capacity compared with the more explicit survey conducted by the Census Bureau; at the time of Shapiro's analysis, Federal Reserve estimates continued to give primacy to the McGraw-Hill/DRI survey, but subsequently that survey was supplanted by the Census survey as the primary source for utilization rates.[6] Another aspect of Shapiro's critique focused on empirical properties of the Federal Reserve's actual estimates; in particular, he assessed the ability of industry utilization rates to predict relative price changes (specifically, price-wage margins). That relationship pertains to an aspect of producer cost structures we shall discuss later. But now let us turn to the relationship between capacity utilization and the overall price level.

Capacity Utilization and Inflation

Critics of capacity utilization as an inflation indicator tend to oversimplify their description of both monetary policy formulation and the inflationary process. For example, an article that appeared in the *Wall Street Journal* on February 14, 1995, showed a chart of manufacturing capacity utilization and consumer price inflation from 1967 onward. The article posited that the switch in the correlation from the 1970s (when both capacity utilization and inflation were high) to the latter half of the 1980s and 1990s (when capacity utilization again was relatively high, but inflation remained well below the peaks of the 1970s) indicated that monetary policy should not be guided by using capacity utilization as an indicator of inflation.

Certainly, basing monetary policy on a single indicator would be naive. A simple relationship between capacity utilization and the overall inflation rate does not exist. Influences on inflation other than resource utilization routinely appear in economic models. For example, some of our inflationary episodes appear to have been exacerbated, if not initiated, by supply shocks, such as those that caused the sharp run-ups in the prices of food and energy in the 1970s. Economic developments abroad and foreign exchange rate swings can affect domestic inflation directly through changes in prices of imports (because our market basket also in-

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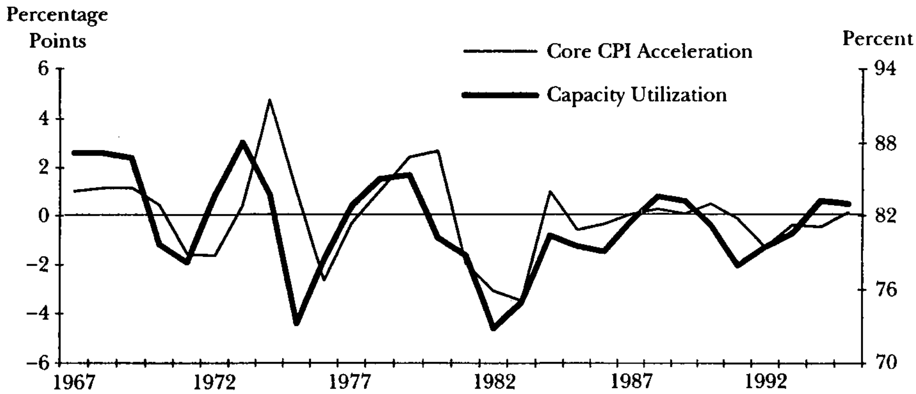
stocks, which provide three-digit industry detail and reflect adjustments for losses of production capability due to economic decay rather than for losses of value due to economic depreciation, are described in Mohr and Gilbert (1996).

[6] A comprehensive revision of industrial production and capacity utilization was published in 1990, which affected capacity utilization statistics back to 1967 (Raddock, 1990). In the 1990 revision, the Census Bureau's survey became the primary source data for manufacturing utilization insofar as possible; in the revised statistics, the individual series in manufacturing were designed to produce subtotals, primarily at the two-digit SIC level, that remained consistent with the manufacturing measures for 1948–1966 that remain based on the McGraw-Hill/DRI survey. Thus, average levels of Federal Reserve utilization rates for manufacturing and major industry groups differ from averages of comparable subtotals calculated from detailed industry data in the Census Bureau's survey.

Figure 1
Capacity Utilization and the Acceleration of Core Inflation



cludes foreign-produced goods) and indirectly through "competing goods" effects on domestic strategic price-setting behavior. Monetary policy and the current state of the economy can affect inflation through expectational influences on prices and wages, and many models fully represent nominal income and inflation as monetary phenomena in the long run.

The Fundamental Connection

Only elaborate models can take these and other complexities fully into account. However, somewhat surprisingly, a relatively strong correlation between capacity utilization and inflation can be revealed by excluding the direct effects of food and energy price changes in the inflation measure and subsuming all other inflationary influences in last period's inflation rate. More specifically, although the simple correlation between capacity utilization and overall consumer price inflation is virtually zero (−.02 to be exact) over the 1967–1995 sample period, the correlation between capacity utilization and the acceleration of consumer prices excluding food and energy is noticeably positive (at .53), as shown in Figure 1. As might be expected, the correlation between manufacturing capacity utilization and the acceleration of manufactured goods prices is even higher; using either the producer price index for finished or for intermediate goods excluding food and energy, the correlation between producer price acceleration and capacity utilization is about .65.

In simple time series models, capacity utilization tends to work as well or better than other candidates for inflation indicator variables at the relevant horizons of one to two years (Cecchetti, 1995; Staiger, Stock and Watson, this issue). In multivariate time series models, capacity utilization also tends to be among the most important indicators of inflation. For example, Cecchetti finds that the preferred multivariate time series model for predicting inflation over the coming year includes capacity utilization and only four other variables: the unemployment rate, a monetary aggregate (M2), the price of oil and a sensitive materials price index. Gordon (1989, 1994) has also found that overall U.S. price inflation depends somewhat more closely on capacity utilization than on the unemployment rate, and a study he coauthored reports a similar result for inflation behavior in Germany (Franz and Gordon, 1993).

This is why, in a world where monetary policymakers "look at everything," utilization rates are frequently high on the list of the items to be monitored. Capacity utilization works as a relatively simple predictor of changes in price inflation. That said, choosing capacity utilization over the next best indicator in a bivariate model for predicting inflation, or adding capacity utilization to an otherwise well-specified multivariate model, will give only a modest reduction in the size of the typical model's prediction error. This is because much of the variance in capacity utilization is common to other "business cycle clocks," such as the unemployment rate.

Capacity utilization has the advantage, however, of being more stable over time than other commonly used cyclical indicators of inflationary pressures. For example, in each of the 13 years from 1975 to 1987, the unemployment rate remained above its 5.75 percent postwar mean. Yet inflation did not decline throughout this period; rather, it picked up sharply in the late 1970s when capacity utilization rose well above its 82 percent postwar mean. The prevailing potential growth rate of the overall economy also is difficult to gauge. For example, the long-run growth trend of real GDP in the United States appears to have slowed since the 1970s. A 10-year average of the annualized rate of (chain-weighted) GDP growth fell from about 4 percent in 1970 to about 3 percent in 1980 and was down to about 2.5 percent by 1995. Thus, no simple constant adequately describes the long-run growth potential of U.S. GDP, and any attempt to represent excess aggregate demand as an output gap—that is, the ratio of actual to potential output—necessarily is predicated on a specific model of how potential output evolves (McCallum, 1994). By contrast, as pointed out in Tinsley and Krieger (1995), the Fed's capacity index offers a survey-based output trend for the industrial sector.

Nonaccelerating Inflation Rate of Capacity Utilization

Some of the earliest interest in capacity utilization as a predictor of price inflation was expressed by researchers at the London School of Economics, where A. W. Phillips was developing his related ideas on the correlation between wage rate changes and unemployment (Corry, 1995, p. 367). Subsequent emphasis on the expectations-augmented Phillips curve, in which wage changes were modeled as also depending on expected price changes, increased the interest in the separate modelling of prices, given wages. For example, Perry (1966), in a model that considered wages, prices and profits as jointly endogenous, used capacity utilization to explain the markup of manufactured goods prices over labor and materials costs.

To estimate a "nonaccelerating inflation rate of capacity utilization," or NAICU, McElhattan (1978) was among the early investigators who assumed that capacity utilization could do the double-duty of reflecting the extent of slack in the labor market for the wage equation and the degree of excess demand in the product market for the price equation. After examining estimates of the implied reduced form, she settled on a specification that explained inflation with the lagged value of inflation plus a term proportional to the deviation of capacity utilization from a constant. McElhattan found that for each percentage point capacity utilization exceeded 82 percent, inflation would accelerate by about 0.15 percentage point, which is the basic correlation shown in Figure 1.

More refined versions of the reduced-form relationship between inflation and capacity utilization have confirmed a NAICU of about 82 percent, including McElhattan (1985), Franz and Gordon (1993), Bauer (1990), Garner (1994), Gordon (1994) and Johnson and Katz (1995). Generally, reflecting the long-term stationarity of capacity utilization, the variation in the point estimate of the NAICU over subsamples that occurs is small. The NAICU parameter is estimated imprecisely, with a 95 percent confidence interval that ranges from about 78.5 to 83.5 percent. However, similarly wide confidence intervals must be attached to estimates of the nonaccelerating inflation rate of unemployment, or NAIRU (Staiger, Stock and Watson, this issue). Note that the variability of capacity utilization over time is much larger than the variability of the unemployment rate, and each percentage point in a typical confidence interval for the NAIRU is comparable to about 2.5 percentage points in the confidence interval for the NAICU.

International Influences on Inflation

The expansion of international trade over the past 35 years has been significant. In assessing this "globalization" of the U.S. economy, some commentators have opined that goods prices are now set in international markets, so a measure of global resource utilization should be substituted for domestic capacity utilization. However, this argument appears far overstated. Tracking the extent of resource utilization abroad has proven to have little incremental value for predicting aggregate U.S. domestic inflation, once one knows the rate of domestic capacity utilization (Garner, 1994). In general, the measured effects of international influences on U.S. inflation tend to be small and imprecisely estimated.

One reason is that international business cycles are fairly synchronized, so usually a measure of U.S. capacity utilization sends qualitatively the same signal about inflationary pressures as foreign measures of resource utilization (Orr, 1994). A second reason is that although foreign penetration of U.S. markets has grown substantially, the proportions are still fairly small for most industries. In general, the few industries for which competitive pressure from slack foreign capacity on domestic prices appear significant are some "upstream" producers of intermediate materials, rather than producers of final consumer demand items (Kan, Krieger and Tinsley, 1989).

Moreover, tight and loose capacity utilization in other countries is not always passed directly into the U.S. market. As a purchasing power parity model of exchange rates will predict, exchange rate movements often dilute or counteract the effects of foreign capacity utilization on import prices (Hooper and Mann, 1989). For example, in the early 1990s, weakness in the Japanese manufacturing sectors persisted longer than in the United States. Yet the low Japanese utilization rates did not depress U.S. prices of Japanese imports. Increases in the yen-to-dollar exchange rate boosted importers' costs in dollar terms and more than offset declining yen prices for goods (Orr, 1994). Or at some times and from some countries, foreign-produced goods are priced to the U.S. market to maintain or expand market share, a pricing strategy that seems especially prevalent among exporters from emerging countries in Latin America and Asia (Johnson and Katz, 1995).

When it seems important, international influences on inflation can be captured in empirical inflation models directly, by including import prices or a measure of foreign-domestic price differentials. But the world economy has not yet reached a point where foreign capacity utilization seems a useful predictor of U.S. domestic inflation.

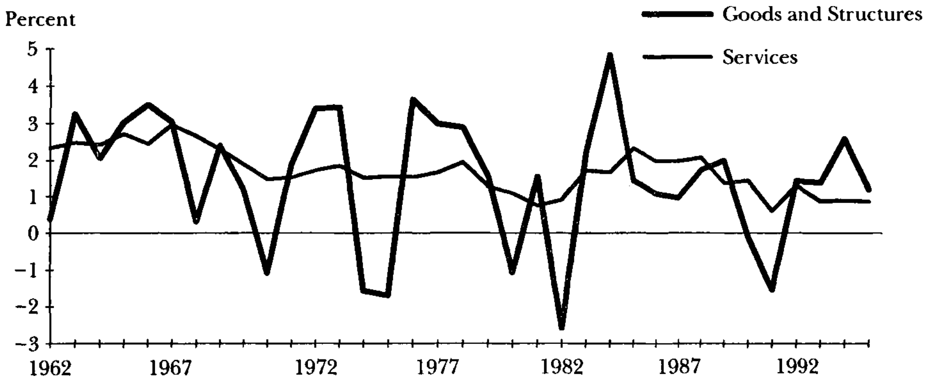
Capacity Utilization as a Cyclical Indicator

The predictive power of factory operating rates for inflation has endured because capacity utilization in manufacturing is indicative of the cyclical state of overall aggregate demand. Most of the fluctuation in aggregate output comes from changes in the demand for goods and new structures; by comparison, final demand for services is relatively stable, as shown in Figure 2. The correlation between annualized changes in the real output of goods and structures and the Federal Reserve's index of capacity utilization for manufacturing, the main goods-producing sector, is about 0.9. In short, capacity utilization in manufacturing is indicative of the cyclical state of the overall product market because the final demand for services contributes little to overall business fluctuations.

The predictive power of factory operating rates for inflation also has endured because capacity utilization in manufacturing is a correlate of the cyclical state of the labor market. In the short run, with capital and technology relatively fixed, changes in aggregate demand result primarily in changes in labor input. Again, most of the fluctuation in private employment occurs among those engaged in the production and distribution of goods and structures, while employment elsewhere contributes relatively little, on balance, to fluctuations in aggregate employment.

One often hears reports that the service sector has been growing rapidly, which suggests that a point may have been reached in which an inflation modeler is ill-advised to base overall inflation predictions on a measure of resource utilization drawn from the main goods-producing sector, manufacturing. For this to be so, goods and services prices would have to behave in a fundamentally different manner, so that the changing product mix of output would create instability in the parameters of the aggregate inflation model. In fact, core measures of goods and services consumer price inflation have relatively similar cyclical patterns, as any macrotheory that emphasizes the wage and price expectations components of inflation would predict. Wage rate changes across private industries have relatively similar cyclical patterns, reflecting the effects of past

Figure 2
Contributions to GDP Growth



and expected overall price changes on wage increases, as well as mobility of labor and spillover effects; this similarity shows through in goods and services price changes.

The second answer to a concern over the relative growth of service industries is to point out that while this growth has been large in terms of employment, it has not been so large in terms of output. True, the goods share of nominal personal consumption expenditures in the national income and product accounts has drifted down from 56 percent in 1967 to 42 percent in 1995. But in real terms, given that price inflation in services tends to run a few percentage points above goods price inflation, the decline was less, from 49 percent to 44 percent. More broadly, the goods share of total real output produced by U.S. businesses to meet final demand has remained stable at just about 50 percent for the past 35 years, as shown in Table 1. New building activity has diminished in importance, while output of services has grown. Moreover, as in the past, the output share of durable goods and structures stands at about 33 percent, and, much as in the past, spending for items in these segments of final demand is most likely to be affected by monetary policy (Bernanke and Gertler, 1995). Thus, spending on goods and, to a lesser extent, new structures remain significant components of U.S. real final demand. The product mix has changed steadily over time, but not in a way that would cause a structural break in an aggregate inflation model.

The stimulus from an economywide trend toward investment in information technology has been reflected in a manufacturing sector that continues to increase production healthily. In real terms, the share of gross business product originating in the manufacturing sector, which stood at 25.2 percent in 1979, remained little changed at 23.5 percent in 1994, with the output of computers and peripheral equipment, semiconductors, as well as communication

Table 1
Share of Business Output by Major Type of Product
(based on chained 1992 dollar annual data)

	1960–1973	*1973–1979*	*1979–1990*	*1990–1995*
Goods	49.4	49.7	49.9	50.4
Structures	17.8	14.8	13.2	11.2
Services	31.8	34.9	36.6	38.4
Durable Goods and Structures	32.6	33.2	32.7	32.6

Note: Gross business product excludes housing.
Source: Authors' calculations using annualized data from Tables 1.4 and 1.8 of the NIPAs.

equipment and related apparatus accounting for much of the robustness in recent years.[7] Clearly, the notion that ours is a new "information-driven" economy does not undermine the usefulness of capacity utilization in a macroeconomic sense. Information-related manufactured products constitute a large share of business capital expenditures and have been an impetus to final demand for the past 15 years.

The remaining question about the reliability of capacity utilization with regard to advanced technologies is whether the productivity gains from the new technologies are adequately captured, so that capacity utilization remains an appropriate macroeconomic indicator of tightness in production costs. Recall that the capacity measures rely on survey evidence. Investments in flexible technologies and the like are recorded by respondents as increases in capacity, and the productivity gains that result from their use appear in both the numerator and denominator of utilization measures.

Someday, perhaps, the adoption of flexible manufacturing techniques may mean that producers' cost functions are not as sensitive to changes in output as they would be without flexible techniques. However, as discussed above, empirical studies suggest the relationship between capacity utilization and inflation continues to be robust.[8] Already by 1988, certain industries had already made considerable progress toward the adoption of flexible machining and assembly systems; in the

[7] Even though all nonagricultural goods and about half of the value of new structures consists of manufactured products, the goods and structures business output share is much larger than the manufacturing business output share because the former also includes gross product originating in the distribution sector (transportation, wholesale and retail trade), as well as in mining and agriculture.
[8] On the other hand, the introduction of flexible techniques and related technologies has led to a shortening of production lead times, suggesting that the timing of a production response to an increase in demand (orders) has quickened as a result of their introduction and expanded use. Thus, the order backlog (the ratio of unfilled orders to shipments in manufacturing), a survey-based series frequently proposed as an excess demand measure, now has longer-run properties that confound simple efforts to use it as a cyclical indicator.

fabricated metals, machinery, transportation equipment and instruments industry groups (SICs 34–38), more than 40 percent had installed numerically controlled machines by 1988; about 25 percent used computers on the factory floor; and about 11 percent had machines that fully automated materials handling, from acceptance of raw materials through delivery of finished products (Dunne, 1991). Yet the macroeconomic indicator value of capacity utilization has remained significant as the further application of advanced technology has continued to reshape manufacturing production.[9]

Microeconomic Issues

Capacity utilization involves a set of related microeconomic issues. Looking more deeply into microeconomic theory and into how respondents answer the capacity utilization surveys has helped develop an understanding of what is truly meant by capacity, how it relates to the economic notions of fixed and variable costs, and what the actual processes are by which the economy moves toward fuller capacity utilization. Exploring these issues also suggests sources of the predictive power of capacity utilization for price changes.

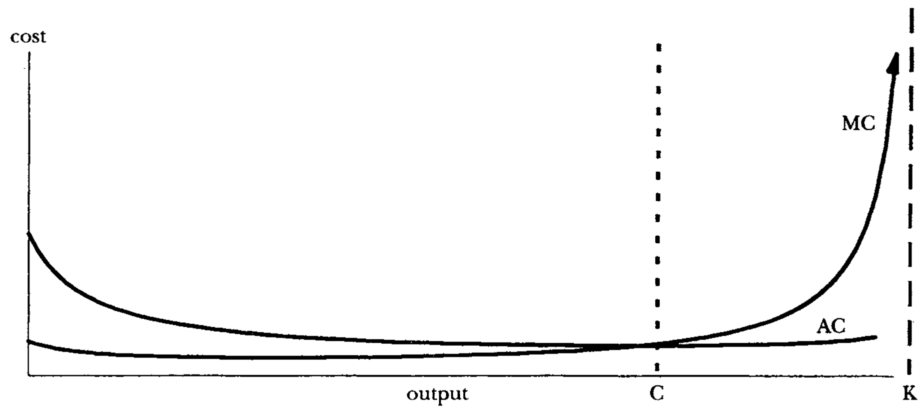
Utilization and Marginal Costs in Theory

We first present a simple example that illustrates how high and rising capacity utilization could lead an individual manufacturing plant to increase prices. The survey definition of capacity underlying the Federal Reserve measure is closest to one of the concepts articulated by Klein (1960), in which capacity output is defined in terms of a full-input point on a production function. Capacity output is the level of output attainable by "fully employing" the variable factors of production, given the current technology and keeping fixed factors at their current levels. For this definition to be complete, the full-employment level of variable factor inputs needs to be defined, and the distinction between variable and fixed factors needs to be precise.

A straightforward theoretical illustration of the relationship of utilization and marginal costs can be derived under the assumption that the full-input level of the variable factors means applying such factors without limit, to the point where the marginal productivity of all variable inputs drop to zero. Figure 3 presents an example (used in the Klein article) where a producing establishment's total costs grow infinitely large as output approaches a saturation level K, which is determined by the size of the capital stock. The corresponding marginal costs, shown in the figure, fall over the initial range of output, are

[9] See the statistical results of a 1993 survey of advanced technology use in manufacturing, U.S. Department of Commerce, Bureau of the Census, *Current Industrial Reports*, "Manufacturing Technology: Prevalence and Plans for Use," 1994.

Figure 3
Capacity Output and Marginal Costs



relatively flat but increasing through the point of minimum short-run average costs (denoted by *C*) and then turn up sharply as output approaches the saturation level.

For a perfectly competitive market with price equal marginal cost, this diagram illustrates the possibility that changes in microlevel prices will be positively correlated with the level of and changes in capacity utilization of the producers. If capacity is defined as the saturation output level *K*, then demand-driven increases in output and utilization lead to higher prices because marginal cost is upward sloping in the relevant range. Furthermore, the pace of price changes is positively correlated with the level of capacity utilization because marginal cost is more steeply upward sloping at higher levels of utilization.

This example does isolate the basic considerations. However, it does not provide very firm microfoundations for the empirical relationship between capacity utilization and prices for a number of reasons. First, the operational definition of capacity utilization does not rely on specifying the "full-input" level of variable factors as the saturation point. Sustained peacetime production at a point of such completely diminished returns is unrealistic, and the Census survey tries to elicit information on more realistic constraints on a producing establishment's output capability (McGuckin and Zadrozny, 1988). Second, this simple theoretical example is posited in a partial equilibrium context and does not contain the additional assumptions needed to isolate the influence of rising capacity utilization on the various components of marginal costs. For example, the upward slope of the marginal cost curve can derive from an upward-sloping wage schedule (say, from overtime premia), from diminishing marginal productivity of labor, or from the increasing marginal costs of other variable factors of production.

Distinctions Between Fixed and Variable Costs in Survey Data

The respondents to the Census survey on capacity utilization indicate their output capability at a fully employed level of variable factor inputs, assuming normal downtime and the prevailing product mix. Early versions of the Census survey explicitly asked respondents to identify the fixed factors that determine capacity, and the responses showed that not all manufacturing plants see fixed and variable factors similarly (Mattey and Strongin, 1995). For illustrative purposes, we discuss three technology types that depend largely on the shutdown cost aspect of the typical production facility. Within each technology group, adjustment patterns for individual establishments are considerably more homogeneous than results for the manufacturing sector as a whole.

Assembly operations, which predominate in manufacturing, can be taken to enjoy relatively small shutdown and start-up costs, but they must be thought of as divided into two relatively distinct technology types. The first is a pure assembly-line operation, which routinely varies the normal workperiod of the plant to adjust actual output. That is, pure assemblers vary the short-run flow of capital services from a fixed capital stock by adjusting the workperiod of capital. This occurs by lengthening the duration of existing shifts, especially when faced with small or transient demand shocks, or by adding an additional shift, when faced with larger and more persistent changes (Mattey and Strongin, 1995; Beaulieu and Mattey, 1996). Such assembly plants, which include the well-known example of auto assemblers, tend to operate with a relatively fixed number of employees per shift and a preset "speed" at which materials and components flow through the assembly line. They primarily adjust labor input and the level of output at capacity through the duration of operations (Aizcorbe, 1992; Bresnahan and Ramey, 1994). Accordingly, for defining the full-input levels of the variable factors of production at capacity, these and related assemblers in the capacity survey focus on a realistic maximum duration the plant can run.

The second kind of technology is another form of assembly operation, this time organized into more flexibly operated "workstations" rather than rigid assembly lines; for example, apparel establishments that are a collection of sewing machines doing the same job. As with pure assemblers, shutdown and start-up costs are small, but plant workperiods are not routinely varied by lengthening existing shifts or adding and eliminating additional shifts. Short-run output changes in the workstation group occur primarily through the duration and intensity of the workperiod at the individual workstations. Accordingly, changes in plant workperiods explain less of the variation in actual and capacity output for manufacturers with workstations than for pure assemblers (Mattey and Strongin, 1995).

A third technology is "continuous processors," who face large shutdown and start-up costs and prefer normally to operate nearly 24 hours per day, seven days a week: for example, an oil refinery or paper mill. Plants with this technology do not shut down production except under very adverse demand conditions, when the plant will be shut down for weeks or months at a time. Rather, continuous processors adjust the plant's consumption of materials to achieve short-run changes in output, both in terms of total quantity and product mix (Bertin, Bresnahan and Raff, 1993). Continuous processors usually expand capacity by relaxing physical capital constraints. Accordingly, when answering a survey on capacity utilization, these respondents regard the capital services implied by a fixed capital stock and a fixed duration of its use to be the primary determinant of capacity.

The logic of how high-capacity utilization leads to higher costs is somewhat different for these various technologies. For assemblers with workstation technologies, the output expansion takes place along factor usage paths where the ratio of capital services to labor input is relatively fixed, but the number of bundles of such inputs is varied. As in the simple theoretical example, this suggests relatively flat marginal costs until the number of employed workstations reaches a maximum. On the other hand, the short-run marginal costs faced by pure assemblers depend, in large part, on what happens as the plant is run for more hours. As new shifts are added, these assemblers may experience an initial range of increasing returns to scale, especially when starting from a point where employee workweeks are short, and lines are not fully staffed. However, given a fixed number of fully staffed shifts, marginal costs will usually slope upward, and output increases must be attained by lengthening working weeks, incurring overtime premia, using more costly materials and pushing the limits of available facilities. Note that some part of the upward slope to the cost curve for assembly operations derives from an upward-sloping wage schedule. Excluding the effects of an upward-sloping wage schedule, the shape of marginal costs may be quite flat over the range of normal output variation (Lucas, 1970). As the plant comes close to working flat-out, however, marginal costs slope steeply upward as in the simple theoretical example.

The short-run marginal costs faced by continuous processors can also show significant scale economies over some infrequently visited range of output. For example, the resumption of a shuttered facility typically involves nontrivial start-up costs, and the plant's adjustment back to a profit-maximizing preferred level of operations will be tracing out, for a time, the downward-sloping region of marginal costs. However, once the available capital has been put fully into use, marginal costs slope steeply upward, as in the simple theoretical model. Indeed, specialists often regard capacity measures for continuous processors, which are found in industries such as aluminum, steel, petroleum refining, paper, cement and basic industrial chemicals, as representing near limiting values on production.

Do Supply Curves Slope Up?

Other things equal, an increase in capacity utilization at a manufacturing plant will be associated with an increase in its output price, assuming that output is increasing because the demand curve has shifted outward along an upward-sloping supply (marginal cost) curve. However, the rise in price will not necessarily equal the rise in marginal cost if the firm operating the plant were able to exploit market power; in that case, the markup of price over marginal cost would not have a simple relationship to current output levels. Alternatively, even if the plant were in a competitive market, it might be operating in a range with short-run scale economies and would maximize profits by increasing utilization and pushing down prices as it moves along a downward-sloping region of the supply curve. Thus, in the presence of either market power or short-run increasing returns, economic theory admits the possibility of a negative correlation between capacity utilization and price changes. Naturally, the prevalence of short-run decreasing versus increasing returns and of competitive versus noncompetitive market structures is an empirical matter.

Evidence for the possible importance of market power or short-run increasing returns appears in a pair of provocative papers. Hall (1988) found that price appeared to exceed marginal cost in more than half of the 20 two-digit SIC manufacturing industries, and he concluded that the finding reflected short-run increasing returns to scale (Hall, 1990). In this context, Shapiro (1989) noted that the increasing-returns view implies that changes in industrial output could primarily reflect changes in the capacity of industry to produce. However, the FRB estimates of capacity growth do not show such short-run variability. Shapiro reasoned that if (mis)measured increases in capacity utilization are not accompanied by rising markups of prices over wages, this could be evidence in favor of short-run increasing returns. He suggests that during a boom in own-industry output, wages do tend to increase, but labor and other factors of production are used more efficiently, driving down overall marginal costs.[10]

Although the econometric evidence for increasing returns does not seem to be particularly robust (Bartelsman, 1995), the increasing returns interpretation is quite plausible for pure assemblers, for whom one expects a negative correlation between output changes and marginal costs for some ranges of demand shocks. Broadly speaking, for industries dominated by pure assemblers, such as the motor vehicles industry, disaggregate industry studies have not yielded significant and positive correlations between own-industry capacity utilization and changes in own-industry prices or price-wage margins. However, one difficulty of interpreting the evidence on increasing returns from disaggregate industry studies is that shocks to factor prices other than wages might occur frequently enough and in sufficient magnitude to cause output prices, given wages, to move inversely with quantities. When appropriate (relevant and exogenous) demand-side instruments are used to estimate the relationship between prices and output, the evidence that supply curves tend to slope upward becomes clearer, particularly for many materials-producing industries, which tend to be continuous processors (Shea, 1993a,b; Tinsley and Krieger, 1995).

In general, at the disaggregated industry level, empirical evidence on the relationship between capacity utilization and producer price changes does not yield

[10] Shapiro's evidence essentially is that the markup of producer prices over wages is not very procyclical, that is, that prices do not increase faster than wages when utilization is high. A more interesting question is whether the markup of prices over trend unit labor costs is procyclical, because persistent changes in labor productivity will affect the wage-price relationship, independent of the demand conditions captured by capacity utilization. Also, a more comprehensive measure of labor costs—including benefits, not just wages and salaries—is more relevant.

a consistent story. But given the heterogeneity in producer cost structures, the lack of a single consistent story in the disaggregated industry data should not be surprising. At more aggregate levels, the predictive power of utilization for price changes under normal ranges of changes in demand would seem to derive in part from the correlation between capacity utilization and wage and overtime premia pressures, and in part from the fact that broad-based increases in capacity utilization tend to bid up the prices of other relatively inelastically supplied factor inputs, such as basic industrial materials.

Conclusion

The construction of capacity utilization, like the construction of almost any macroeconomic statistic, involves a combination of people answering surveys and government statisticians aggregating their responses and other data into a single number that can be second-guessed. Yet the concept of capacity utilization continues to play a useful role in our thinking and analysis of the inflationary process. Movements in capacity utilization can be taken as stemming primarily from shocks to aggregate demand, which push the economy along an upward-sloping aggregate supply curve. The notion that inflation begins to accelerate when capacity utilization exceeds a threshold near 82 percent has been quite firm over the decades.

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