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Measurement and Price Effects of Aggregate Supply Constraints

The Keynesian notion of short-run full capacity (Keynes identified it with "full employment"), defined as a level of output beyond which "a further increase in the quantity of effective demand produces no further increase in output and entirely spends itself on an increase in the cost unit" (Keynes 1936, p. 303), remains an empirically underdeveloped aspect of macroeconomics. Aggregative measures of capacity utilization and of potential output do exist, of course. Such measures have been used in econometric price equations as "demand pressure" variables, supplementing cost variables. However, as these measures are derived—by a value-added (or similar) weighting of industry or sector utilization rates—they conceal short-run conditions of effective global full capacity or near

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capacity when, in periods of high demand, there are substantial variations among sectors in the degree of utilization or when there are shortages of materials or of specific kinds of labor (throughout the economy or in specific geographic areas), etc.

It is unlikely that as such bottlenecks first develop, aggregate supply becomes suddenly inelastic, since there is always some potential for substitution (by both producers and consumers) by increasing hours of work, running down inventories, deferring replacement of plant and equipment, and so forth. As bottlenecks become increasingly widespread and more critical, aggregate supply slopes upward more and more sharply and with sufficiently strong increases in demand could become practically vertical. In the short run, this could occur when aggregate utilization indexes register less than 100 percent.

When aggregate supply is perfectly inelastic, measured utilization rates fail to reflect the true state of demand and resulting price pressures (with the trivial exception of the case in which demand equals supply just at the point where supply becomes inelastic), since they are ex post rather than ex ante measures.[1] But even in the situation (more likely to be encountered) of near capacity, true demand pressures on prices are likely to be missed by conventionally measured overall utilization rates—even with strongly nonlinear formulations—unless such measures are biased upward for reasons not associated with bottlenecks.

This paper is focused mainly on the problem of measuring utilization near effective capacity and its implications for predicting price behavior. My primary purpose is to develop an index of capacity utilization that takes into account capital capacity (measured at the Standard Industrial Classification two-digit level), though not availability of labor and raw materials, as a cause of supply bottlenecks. A "bottleneck-weighted" index is then used in price equations in place of the ordinary index to determine whether improved performance results.

In section I, theoretical problems associated with measurement of utilization—in particular, the bottleneck problem—are reviewed. In section II, the construction of a bottleneck-weighted utilization index is described. In section III, the ordinary and bottleneck-weighted utilization rates and, as another alternative, the Federal Reserve Board's newly published major materials index of utilization are compared as explanatory variables in regressions for manufactured goods prices. In section IV, the implications of short-run aggregate inelastic supply in relation to the estimated price equations are briefly described. In order to determine such supply limitations, I apply part of a procedure I had previously developed (Hirsch 1972) for imposing supply constraints in the context of a macroeconometric model. A summary section follows.

I. CAPACITY UTILIZATION AND BOTTLENECKS: THEORETICAL ISSUES AND EMPIRICAL MEASUREMENT

Meaning of Capacity

The problems of defining and measuring capacity at the level of the firm have been much discussed and do not need extensive review here (see, e.g., de Leeuw 1962, Klein 1960, and Phillips 1963). Neoclassical theory implies minimum average cost (MAC) as the criterion for the optimum production level and hence of "capacity." On the theoretical level, there is no ambiguity in this concept for the single-product firm or for the multiproduct firm producing a technologically fixed mix of outputs. Empirically, there is much ambiguity if the production process of the firm is not continuous (i.e., does not take place twenty-four hours a day, seven days a week) or if average costs vary little over a wide range of operating rates. Ambiguity also arises in the case of the multiproduct firm for which a choice of mix is available.

The MAC criterion of capacity would be empirically useful in explaining investment and pricing behavior if MAC output were a threshold point such that output increases have a significantly greater impact on the magnitude of investment or price beyond that point than before. Some questionnaire surveys of operating rates include a question on the "preferred" operating rate in an effort to get a measure based on this concept.[2] It is then desirable for regression purposes that a substantial number of observations of the actual operating rate be above the preferred rate, but this is not the case.

De Leeuw (1962) has suggested as an alternative to MAC the level of production at which short-run marginal cost exceeds minimum short-run average cost by some fixed percentage; rapidly rising marginal costs would ensure that there are appreciable upward pressures on prices as capacity is approached.

The actual operating rates reported in utilization surveys are based on capacity in engineering rather than economic terms. For non-continuous-process industries, this involves the concept of the "normal" workweek, with due allowance for normal breakdowns, maintenance, and vacations. For continuous processes, capacity represents the firm's view of maximum physical production potential. It should also be noted that the firm's fixed real assets, i.e., its plant and equipment, constitute the unambiguous basis of capacity measurement; other resources are thus implicitly assumed to be available to the firm in elastic supply.

Bottlenecks and Aggregate Capacity

A problem of fixed capital bottlenecks, or capacity balance, arises in the measurement of capacity utilization basically because of nonhomogeneity of capital goods used in interdependent productive processes. The failure of available indexes of capacity utilization to take into account sectoral bottlenecks has been recognized for some time (see, e.g., Klein 1960; Klein and Summers 1966, pp. 49–50; and Phillips 1963). This issue surfaced again in a recent set of papers presented at the Brookings Panel on Economic Activity.[3]

Although there has been no deliberate effort to incorporate bottlenecks into economy-wide or sector-wide measures of capacity utilization, two attempts—by Malenbaum (1969) and by Griffin (1971)—have been made at the industry level. In each case the "industry" consists of multiproduct firms. Three technological aspects of these multiproduct industries are relevant from the standpoint of aggregate capacity measurement: each firm produces a number of distinct products with the same factor inputs; a number of productive processes, each having its own capacity, is available to the firm (industry); the outputs of the various processes are interdependent. Both studies use a linear programming (LP) approach to capacity measurement.[4]

Can a methodology analogous to that of Malenbaum or Griffin be applied to broader aggregates such as total manufacturing or the total private economy? The LP approach depends on the existence of multiple processes for producing the same set of commodities. However, the Standard Industrial Classification divides industry into mutually exclusive groupings by output categories, resulting in a one-to-one correspondence between processes and products (more precisely, product groups). Consequently, in Malenbaum's framework, determination of capacity under the assumption of a fixed mix would reduce the analysis to the trivial one of identifying the bottleneck industry and, under the assumption of a rigid input-output technology, defining the utilization rate of that industry as the one applicable to the economy (or subsector) as a whole. Thus, realistically, no such analogue exists.

Well before the studies of Malenbaum and Griffin, Klein (1960) proposed (but did not apply) an alternative approach for dealing with the bottleneck problem at the level of the whole economy. Klein's procedure, which involves iterative solutions of an input-output system, depends on arbitrary adjustments to final demand as sector after sector reaches its output capacity and on the assumption—rather unrealistic for periods as short as one quarter—that capacity can be expanded in the bottleneck sectors to supply needed additional output to other sectors. Because of its arbitrary and unrealistic aspects, as well as its being hard to apply, there is little to recommend this approach.

Our problem, then, is to develop a simpler, more pragmatic method of dealing with the bottleneck problem at the level of the economy or a broad sector, such as manufacturing, one that is specifically designed to explain price behavior. The method devised for this study makes use of existing capacity utilization estimates by industry. Its formulation depends on the assumed nature of the relationship between capacity bottlenecks and pricing behavior, to which I now turn.

Capacity Bottlenecks and Pricing Behavior

The precise nature of the relationship between capacity bottlenecks and pricing behavior depends on the impact that such bottlenecks have on aggregate supply. Two kinds of bottleneck situations may be postulated.

The first kind is extreme and has already been alluded to in the previous subsection as being simplistic. Full capacity, in the sense of an absolute (short-run) limit on production, has been reached in (at least) one industry which produces exclusively (or almost so) for intermediate use. Then, under a rigid input-output technology, production is limited everywhere; that is, aggregate supply is perfectly inelastic and prices become demand-determined. The extent of price increase depends on the position of the aggregate demand schedule and on lags in the adjustment of prices to market-clearing levels. The industry's, and therefore the economy's, utilization rate would be 100 percent; and so aggregate output could not be increased further. (In this situation the utilization rate becomes an inadequate indicator of excess demand pressure.)

The other (more likely) situation is one in which aggregate supply is not absolutely restricted. That will be the case either if "full" capacity in the bottleneck industry is not an absolute ceiling, but corresponds to a lower output level, such as MAC or de Leeuw's critical ratio of marginal to average cost, or, if it is at a maximum physical production level, there are substitution possibilities for the users—producers or consumers—of the industry's output. Bottleneck formation is thus viewed as a cumulative process, rather than as an abrupt phenomenon, so far as aggregate price behavior is concerned.[5] Accordingly, a utilization index that incorporates bottlenecks should do so in a gradual way. Nonetheless, rising prices in the bottleneck industries are passed on as cost increases to other industrial and final users.

II. A BOTTLENECK-WEIGHTED INDEX

Which Utilization Index Should Be Modified?

Six aggregate utilization series are available, five directly published and one derivable from a capacity index. These represent a variety of methodologies having varying degrees of coverage.[6] Each one has its own peculiar merits and shortcomings. The article by Perry, referred to previously, provides a careful comparison among four measures of capacity utilization in manufacturing: the McGraw-Hill utilization index, utilization as derived from the McGraw-Hill estimates of capacity, the Federal Reserve Board's (FRB) utilization index for total manufacturing, and the Wharton index. The two others are the series presently published by the Bureau of Economic Analysis (SCB 1974b) and the Federal Reserve Board's special index for major materials (Edmondson 1973).

The McGraw-Hill (1972) utilization index is based on an annual survey of operating rates in large manufacturing firms; thus, quarterly values must be derived by interpolation. A separate question in the survey on available capacity together with industry output data provides an independent basis for evaluating capacity utilization. The FRB's manufacturing index is benchmarked on the McGraw-Hill survey, but is analytically derived in that its movements are based on changes in output (as measured by industrial production) and in capital stock. The latter is a composite measure based on a weighted average of the FRB stock estimate and that implied in the McGraw-Hill capacity series. The Wharton index

(Klein and Summers 1966) is obtained entirely analytically by deriving capacity output by linear interpolation between peak output levels.

The new BEA survey is part of the plant and equipment expenditures survey. It is like the McGraw-Hill survey in that it does not attempt to define "capacity" for the respondent, and responses are obtained on a company basis. It differs from the latter in four ways: (1) Beginning in 1968 it is quarterly rather than annual. (2) The sample is larger and includes small and medium-sized as well as large manufacturing firms. (3) Capacity outputs, rather than current values added, are used as weights. (4) Preferred operating rates are regularly reported.

Finally, the FRB major materials index is compiled as a weighted average from utilization rates for twelve basic primary industries, namely, basic steel, primary aluminum, primary copper, manmade fibers, paper, paperboard, wood pulp, soft plywood, cement, petroleum refining, broad-woven fabrics, and yarn spinning. For each industry, utilization is derived by dividing output by "capacity," the latter obtained in physical units from various governmental and private sources.

For purposes of the present study—since it deals with the problem of capacity balance—it is important that the utilization measure be an explicitly capital-oriented one, i.e., that capacity refer unambiguously to the productive capability of plant and equipment, assuming that other resources are available in adequate supply. This criterion precludes use of the Wharton index because capacity there is obtained by linear interpolation of observed peak levels of output for each two-digit industry. Thus, we do not know whether a particular observed peak indicates that "full" (or optimal) use of capital has been reached in that sector or whether it reflects a peak in demand (the "weak peak" case) or inability to expand output further because of labor or materials shortages. Klein's argument (see note 6) that capital capacity bottlenecks are accounted for is therefore a tenuous one. Nonetheless, this may be so in specific instances, and in that case any further attempt to modify the index for bottlenecks would result in an overcorrection.

Since the FRB major materials index covers only a selected set of industries, it does not serve the primary purpose of this paper, which is to derive a modified utilization measure from a comprehensive set of industry data. Nevertheless, as will be seen in the following section, this index turns out to be useful as an alternative measure and as a benchmark against which to judge the adequacy of the series and procedure that are actually used.

This leaves as candidates for the series for modification the questionnaire surveys and the FRB utilization index. The latter is rejected because of apparent flaws in its methodology which result in the implausibly low utilization figures for recent years.[7]

The McGraw-Hill utilization series was found by Perry to have an apparent cyclical reporting bias, i.e., respondents treat marginal facilities differently at different stages of the cycle, ignoring their existence during slack periods but "discovering" them in peak periods.[8] Despite this shortcoming, the McGraw-Hill index was chosen because it appeared to be superior in other important respects. In particular, it is (at least in principle) free of long-run biases that occur when measures of capacity or capital stock are explicitly required for calculation of utilization rates. Such measures may fail to take adequate account of changes in capital intensity or of the use of capital expenditures for "nonproductive" purposes, such as pollution abatement, which have become prominent in recent years. It also does not suffer from the ambiguities and other shortcomings of the Wharton index. In terms of operating rate levels, as distinct from changes, ". . . the McGraw-Hill utilization survey seems the most believable of the available measures [for total manufacturing]" (Perry 1973, p. 731). Using Perry's methodology for quarterly interpolation and extrapolation, estimates were extended through 1973.[9]

The differences between the BEA and McGraw-Hill surveys also represent advantages of the former over the latter. Unfortunately, for price regressions, the BEA survey provides too few observations, even if quarterly interpolations are made for 1966 and 1967, for which only semiannual estimates are available.[10]

Derivation of Bottleneck-weighted Utilization Index

When utilization rates for the various industry components are all moderate, i.e., are substantially below peak observed levels, there is no bottleneck problem and, therefore, no need to depart from standard weighting methods, such as those based on value added or capacity output. However, when important primary or intermediate processing industries are at or near peak levels, average measures become inadequate indicators of demand-induced price pressures. In that case the utilization rate of the bottleneck industries should dominate the overall index. To achieve this, we derive a weighted combination of the published McGraw-Hill index—the "ordinary" utilization rate—and a bottleneck variant. The weights are made variable, so as to shift between the two measures in accordance with the above criteria and with our discussion in the previous section. This procedure also avoids the simplistic approach of defining the overall rate as the highest sector utilization rate.

The bottleneck rate (U_b) is obtained by weighting each industry's utilization rate by the square of the ratio of the industry's output used as manufacturing input to its gross output, using the 1967 input-output table (SCB 1974a, Table 1, p. 38):[11]

$$U_b = \frac{\sum_{i=1}^{N} r_i^2 U_i}{\sum_{i=1}^{N} r_i^2}.$$

where U_i is the ith industry's utilization rate, and r_i is the ith sector's relative input weight. A quadratic rather than a linear formulation is used in order to give greater dominance to utilization rates of industries which are largely suppliers for intermediate use. Note, however, that no single industry establishes the bottleneck rate.

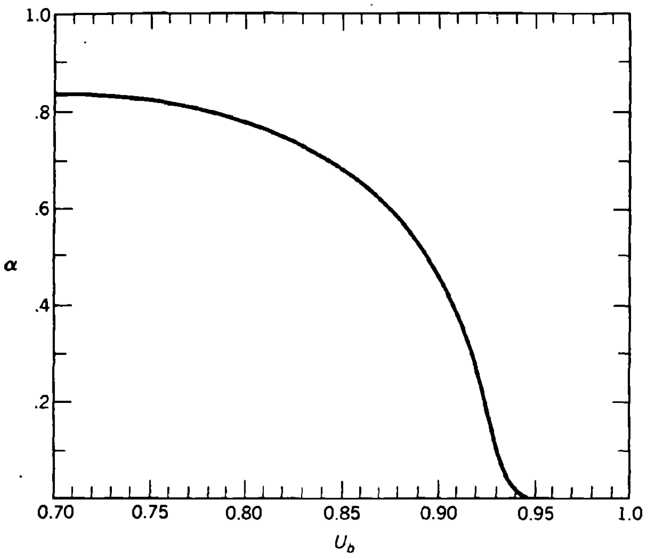
The combined or "bottleneck-weighted" index ($\tilde{U}$) is derived as

$$\tilde{U} = \begin{cases} \alpha U + (1 - \alpha)U_b, & U_b > U \\ U, & U_b \leq U \end{cases}$$

where $\alpha = \exp\{-[\beta/(0.95 - U_b)]\}$. As U_b approaches 0.95 (just above the maximum of observed values of U_b), α approaches zero and $\tilde{U}$ approaches U_b. As U_b falls below 0.95, α rises rapidly and U begins to receive substantial weight. It receives full weight when U_b is no greater than U; thus the formulation assures that $\tilde{U}$ is always equal to or greater than U. β is an arbitrary parameter set at 0.04. This gives a plausible nonlinear shape to α (see Figure 1). Experimentation with other values of β of the same order of magnitude revealed that $\tilde{U}$ is fairly robust with respect to this parameter.

Figure 2 shows U and $\tilde{U}$ for 1954IV–1973IV. For most of this time $\tilde{U}$ either equals or is only slightly greater than U. $\tilde{U}$ lies substantially above U for most quarters during 1955–1957, 1964–1966, and in 1973. Only for still more restricted periods is $\tilde{U}$ greater than 0.90. Thus, the number of observations for which a spread between $\tilde{U}$ and U could make a substantial difference is distressingly small. Unfortunately, moreover, industry detail is limited in the McGraw-Hill survey; a finer breakdown would result in high relative input weights for certain industries whose importance is obscured by aggregation. For all of these reasons, regression tests of the useful-

FIGURE 1



NOTE: U_b = bottleneck rate. For explanation of α, see text.

ness of the bottleneck-weighted index compared to the ordinary index are likely to be sensitive to measurement and specification error; the results reported in the following section should be interpreted in that light.

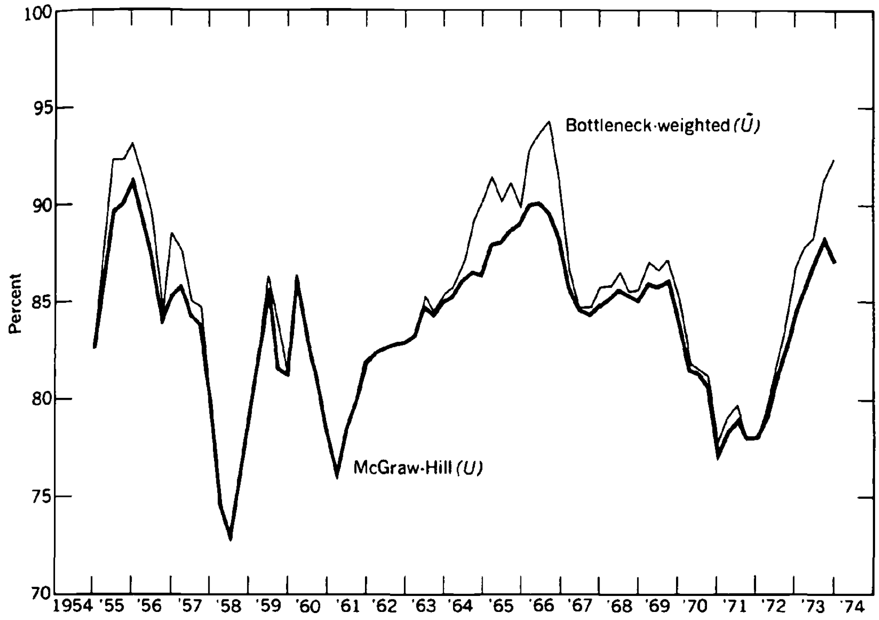
III. TESTS OF MODIFIED UTILIZATION INDEX IN PRICE EQUATIONS

Role and Form of Capacity Utilization in the Price Equation

Capacity utilization appears in addition to cost variables in various econometric price functions as a "demand pressure" variable. It occurs in various forms, although the connection between its alleged role and the specified form is not always made clear.

There are at least two fairly distinct interpretations of utilization as a price determinant, both related to demand. In the first view, it is a cyclical-state variable representing primarily cyclical variations

FIGURE 2 Utilization Rates: McGraw-Hill and Bottleneck-weighted, 1954IV–1973IV



in the degree of effective price competition. As early as 1936, Harrod pointed out that under monopolistic competition the elasticity of demand for a firm would increase in recession and decline in prosperity. Moreover, as demand approaches peak levels, marginal costs may rise sharply.

In the second view, capacity utilization can also represent the degree of aggregate excess demand. In this role utilization is a disequilibrium variable generating corresponding equilibrating price adjustments. In discussing the theory underlying their econometric price equations, Eckstein and Fromm (1968) recognize both roles of capacity utilization. Alluding (albeit implicitly) to the first role, they write (p. 1163):[12]

> When the current rate of production is low in relation to the industry's capacity, i.e., when the industrial operating rate is low, firms will reduce prices as they seek to boost sales and production to permit a better utilization of capacity and thereby to raise profits. Conversely, when production is very high, so that the operating rate of capacity is beyond the optimal, signaling the need for additional capacity, firms will increase price.

Somewhat further on, with more explicit reference to competitive factors, they note (pp. 1163–1164):

> But some elements of locational or product differentiation attach to the sales of most companies in sufficient degree to create some uncertainty in pricing. When operating rates are high, a firm can feel more confident that an increase in prices will not produce a serious loss in sales. Customers will not be able to establish new supply connections and will therefore be more likely to pay the higher price.

Between these two statements, the excess demand role is recognized (p. 1163):

> When operating rates are high, disequilibrium in product markets will be more frequent and larger. Inevitably, high operating rates are associated with delivery delays, shortages, and changes in the nonprice terms of transactions, such as freight absorption and the provision of "extras." These phenomena, in time, are likely to lead to price change.

In incorporating capacity utilization (the Wharton index is used), however, Eckstein and Fromm make no distinction between these two roles: utilization, in level form, represents both roles in both level and change forms of the price equation. Yet, in principle, at least, the two interpretations call for different forms. The competitive aspect calls for utilization as the argument of a variable markup of price over unit labor cost (or labor and materials costs). That is, the level of utilization occurs in addition to cost variables—either multiplicatively or additively—in an equation explaining the price level. Thus, in a first- or relative-difference form of the price equation, the competitive factor calls for inclusion of the change in utilization rather than the level.[13]

When utilization (U) is an indicator of excess demand, we may specify

$$\frac{\Delta P}{P} = f\left(\frac{q_d - q_s}{q_s}\right) = g(U)$$

where P is price and q_d and q_s are, respectively, quantity demanded and quantity supplied. It is not clear a priori what form $g(U)$ should take. There is little reason to presume the existence of excess demand at low and moderate levels of utilization, while (as noted) at high operating rates disequilibrium in product markets will become more frequent and larger. Thus, a strongly nonlinear form of the level of utilization in an equation explaining the change in price is suggested. Such a form is given by the reciprocal of the complement of utilization, i.e., $1/(1 - U)$, hereafter called the reciprocal complement form.

A problem with this formulation is that if a given level of utilization is sustained indefinitely, excess demand is presumed never to diminish as prices rise in response. Continued price increases imply an ever increasing profit share. For short periods, however, it can be assumed that given the (high) utilization rate, as shortages are eliminated by price increases in some sectors, new shortages can appear in others.

Alternatively, a distributed lag of the change in utilization (or of its reciprocal complement) may be used. In that case, an increase in utilization initially increases the rate of inflation, but gradually the latter returns to its original level. Still another possibility is a variable involving the interaction of the level of capacity utilization (or of its nonlinear transformation) with a more direct demand measure, such as sales or new orders (change form).[14]

Data and Forms of Price Equations Tested

Since the utilization index selected for modification is for manufacturing and the bottleneck-weighted index represents that sector as a whole, it made sense to estimate the price equations for total manufacturing only. The dependent variable is the wholesale price index for manufactured goods.

The basic model, of which the estimated price equations are intended as variants, involves a variable markup over unit labor and materials costs.[15] For an industry one might specify the following level form of the equation:

$$P_i = A(ULC_i + UMC_i)^{\alpha}[f(U_i)]^{\beta}(ED_i)^{\gamma}$$

where ULC_i is unit labor cost, UMC_i is unit cost of materials for the ith industry, $f(U_i)$ is a function of the utilization rate (plausibly the utilization rate itself), representing the cyclically variable competitive effect on the degree of markup over cost, and ED_i is an excess demand variable, which may also contain the utilization rate.

Since the wholesale price index for total manufacturing is an average index for manufacturing industries at all stages of processing, the data could not be aggregated simply by using raw material costs for UMC. At each stage of processing beyond the first, costs of semimanufactures as well as raw materials are reflected in input prices, thus presenting an aggregation problem. Nor does ULC suffice by itself—on grounds that the cost of semimanufactures is absorbed by *ULC* upon aggregation—since *ULC* is obtained from compensation per unit of value-added output. It is, moreover, generally agreed that firms view their labor cost in terms of current wage rates and long-run or "normal" productivity (average output per man-hour). Thus, some specification of normal productivity is required (see, e.g., Schultze and Tryon 1965 and Eckstein and Fromm 1968, pp. 1168–1170).

A relative first-difference formulation can largely avoid these problems of measurement and aggregation, though at the expense of reducing the signal-to-noise ratio. In particular, straight-time average hourly earnings may be used instead of unit labor cost, thus absorbing long-run productivity growth into the constant term and abstracting from cyclical and other short-run variations in the mix of straight-time and overtime hours worked, as well as in productivity. I found, as did Eckstein and Wyss (1972) studying two-digit manufacturing sectors, that straight-time earnings give superior results. In addition, when the wage rate is used in conjunction with the utilization rate, the bias due to correlation between productivity and utilization is avoided.

Two basic kinds of change-form specifications were estimated. In the first, the dependent variable is in relative one-quarter-difference form (i.e., P/P_{-1}) and explanatory variables are given with an imposed lag structure: diminishing weights (0.4, 0.3, 0.2, and 0.1) are applied to values (levels or changes) of all variables from t (current quarter) to $t - 3$. Following Eckstein and Wyss, the alternative specification makes the dependent variable $P/(0.4P_{-1} + 0.3P_{-2} + 0.2P_{-3} + 0.1P_{-4})$. This formulation represents a compromise between a one-quarter change, with its relatively large component of measurement error, and a four-quarter change, which makes no behavioral sense and builds substantial serial correlation into the disturbances. Explanatory variables given in change form are expressed in the same way as the dependent variable; thus, no distributed lag effects are implied. Both types of equations may, of course, involve misspecification of lag structures. However, it was felt that for present purposes, empirical determination of the lag structure would unduly complicate the analysis.

Explanatory variables for the equations whose results are reported below include average straight-time hourly earnings, prices of raw materials used in further processing, various demand variables involving the utilization rate, and—as an alternative to utilization variables—the change in the ratio of unfilled orders to shipments.

The variable used to represent the cyclical state of demand is the change in the utilization rate (ΔU). Alternative transformations of U used to represent excess demand include U, $1/(1-U)$, and $[1/(1-U)](NO/NO_{-1})$, where NO is manufacturers' new orders. ΔU must be regarded as possibly representing excess demand instead of (or as well as) the cyclical state of demand in spite of my earlier suggestion that the form of the disequilibrium term should be nonlinear.[16] The statistically "best" formulation, based on the ordinary utilization rate, is then tested with alternative concepts of utilization. (Note, however, that only the excess demand proxy is appropriately thus permuted, since it is not meaningful to incorporate the bottleneck notion into the cyclical state proxy.)

In addition to the ordinary (McGraw-Hill) utilization rate (U) and the bottleneck-weighted rate ($\tilde{U}$), the Federal Reserve Board's major materials index (U_m) was tried as a third alternative. Conceptually, it is more akin to the bottleneck rate (U_b) than to $\tilde{U}$, which represents a compromise between the bottleneck rate and the ordinary rate. However, since it is derived from data sources entirely different from the company surveys that underlie U, it is inappropriate to derive a new bottleneck-weighted rate as a combination of U and U_m, analogous to $\tilde{U}$.

The main reason for including U_m among the tests is that, in contrast to the McGraw-Hill and BEA surveys, the source data are on a product rather than a company basis. Hence, they do not suffer from the distortion that occurs in U_b because of the dispersion of utilization rates for different product lines under the roof of a single company that reports only its average utilization rate. The classification of companies by industry is determined by main activity. If the company mix of products varies over time, U as well as U_b may be distorted.

Empirical Results

Ordinary least squares regressions were run for various specifications of Type I (P/P_{-1}) and Type II (P divided by a weighted moving average of lagged P) forms for 1955IV–1973IV, omitting 1959III, 1959IV, and 1971IV. The first two omissions are to prevent the reduced utilization rates during the 1959 steel strike from distorting the proxy role of that variable. The 1971IV observation is omitted because of the price freeze from mid-August to mid-November (which is essentially reflected in the third-to-fourth quarter change). The subsequent control period is included despite the possible impact of controls on the wage-price relationship because

TABLE 1 Regression Results for Manufactured Goods Prices: Type I

Eq.	Constant	$\frac{AHE}{AHE_{-1}}$	$\frac{PR}{PR_{-1}}$	ΔU	U	$\frac{1}{1-U}$	$\frac{1}{1-U}\frac{NO}{NO_{-1}}$	$\Delta\left(\frac{UO}{S}\right)$	$\bar{R}^2$ $[\bar{S}]$ $\{DW\}$
1.1	.0769 (0.74)	.7021 (6.34)	.1918 (10.34)	.0280 (0.87)	.0246 (2.38)				0.809 [0.00310] {1.74}
1.2	.0855 (0.83)	.7098 (6.50)	.1969 (10.48)	.0298 (0.95)		.000677 (2.72)			0.813 [0.00306] {1.79}
1.3	.1171 (1.09)	.7209 (6.48)	.1575 (5.75)	−.0273 (0.61)			.0000983 (2.17)		0.806 [0.00312] {1.68}
1.4	.1314 (1.22)	.6471 (5.60)	.2131 (10.72)	.0654 (1.94)				.0102 (2.30)	0.807 [0.00311] {1.74}
1.5	.0741 (0.69)	.7224 (6.32)	.2000 (10.18)	.0391 (1.19)					0.795 [0.00320] {1.61}
1.6	.1125 (1.04)	.6543 (5.67)	.2094 (10.39)		.0223 (2.04)			.0040 (0.90)	0.809 [0.00310] {1.73}
1.7	.1140 (1.07)	.6698 (5.83)	.2074 (10.34)			.000629 (2.30)		.0029 (0.64)	0.812 [0.00307] {1.77}

NOTES TO TABLE 1

The dependent variable is P/P_{-1}, where P = wholesale price index, total manufactures (1967 = 100), and the independent variables are defined as follows:

AHE = average hourly earnings, straight time, for manufacturing production workers;
PR = wholesale price index, crude materials for further processing;
U = capacity utilization for manufacturing (McGraw-Hill);
NO = manufacturers' new orders;
UO = manufacturers' unfilled orders;
S = manufacturers' shipments.

$\bar{R}^2$ = coefficient of multiple determination adjusted for degrees of freedom; $\bar{S}$ = standard error of estimate adjusted for degrees of freedom. DW = Durbin-Watson statistic.

those observations, especially for 1973, involve larger spreads between U_b and U than at any other time during the sample period

Table 1 gives regression statistics for various form of Type I equations, using only the ordinary utilization rate.[17] As expected, average earnings and raw materials prices are always highly significant and explain most of the variation in manufactured goods prices. Equations 1.1 through 1.4 each contain the change in utilization together with some excess demand variable. The excess demand variables include the level of utilization, the reciprocal complement multiplied by the relative change in new orders, and the change in the ratio of unfilled orders to shipments. ΔU is clearly not significant in equations 1.1–1.3 and in 1.3 it has the wrong sign. Nor is it significant in equation 1.5, which contains no other excess demand variable, though it is somewhat more potent. In equation 1.4, ΔU occurs together with the change in the ratio of unfilled orders to shipments; there it has borderline significance. Both the ordinary and the nonlinear forms of U are marginally significant at the 5 percent level. Equation 1.2 is slightly superior to 1.1, but is preferred mainly on theoretical grounds (see above). The nonlinear utilization term also does somewhat better than the other two excess demand terms (equations 1.3 and 1.4).

Equations 1.6 and 1.7 are more similar to those tested by Eckstein and Fromm (1968) than are the first five equations. They are less easily justified on the basis of the reasoning presented here, but are included for comparison. The terms involving U do slightly less well in these forms than in equations 1.1 and 1.2, and the orders-shipments term is not significant.

Turning to the Type II equations (shown in Table 2), we find that the ΔU term is not significant and is consistently negative. How-

TABLE 2 Regression Results for Manufactured Goods Prices: Type II

Eq.	Constant	$\frac{AHE}{AHE(L)}$	$\frac{PR}{PR(L)}$	ΔU	U	$\frac{1}{1-U}$	$\frac{1}{1-U}\frac{NO}{NO_{-1}}$	$\Delta\left(\frac{UO}{S}\right)$	$\bar{R}^2$ [S] {DW}
2.1	.1170 (1.71)	.6516 (9.14)	.1790 (15.05)	−.0354 (1.73)	.0555 (4.01)				0.892 [0.00419] {1.44}
2.2	.1471 (2.24)	.6577 (9.62)	.1790 (15.67)	−.0326 (1.71)		.00155 (4.78)			0.900 [0.00403] {1.55}
2.3	.1375 (2.00)	.6798 (9.50)	.1822 (15.25)	−.0288 (1.45)			.00145 (3.88)		0.890 [0.00422] {1.57}
2.4	.1327 (1.84)	.6825 (9.12)	.1784 (14.18)	−.0343 (1.64)				.0234 (2.86)	0.890 [0.00422] {1.57}
2.5	.1366 (1.80)	.6743 (8.56)	.1826 (13.89)	−.0297 (1.35)					0.867 [0.00465] {1.20}
2.6	.1114 (1.62)	.6724 (9.41)	.1719 (14.73)		.0457 (3.57)			.0131 (1.51)	0.891 [0.00421] {1.46}
2.7	.1374 (2.08)	.6752 (9.82)	.1723 (15.32)			.00136 (3.87)		.0110 (1.37)	0.899 [0.00406] {1.55}

NOTE: The dependent variable is in the form $P/P(L)$; for any variable X shown, $X(L) = 0.4X_{-1} + 0.3X_{-2} + 0.2X_{-3} + 0.1X_{-4}$. Terms in U, except ΔU, are in the distributed lag form $0.4U + 0.3U_{-1} + 0.2U_{-2} + 0.1U_{-3}$; ΔU and $\Delta(UO/S)$ are in the form $X - X(L)$.

ever, the other terms improve in significance, while the Durbin-Watson statistics are still acceptable despite the overlapping change form. (The negative coefficients of ΔU suggest that this variable may be capturing short-run productivity effects.) Again, the reciprocal complement form of U does best and has a substantially higher t ratio than in the Type I equations. Hence, a Type II equation form including $1/(1 - U)$ but excluding ΔU was tested as the basis for comparison of different measures of utilization developed in this paper. The reciprocal complement form of U fortunately also allows for maximum differentiation among alternative measures of utilization at periods of peak activity.

The first three lines of Table 3 show regression statistics for price equations with the three utilization variants appearing in the reciprocal complement form and without the nonsignificant ΔU term. The results are disappointing for the bottleneck-weighted index. Equation 3.2, which uses the $\tilde{U}$ variant, yields only negligibly higher values of $\bar{R}^2$ and t ratios for the utilization term than equation 3.1, based on ordinary U. There is also very little difference in the

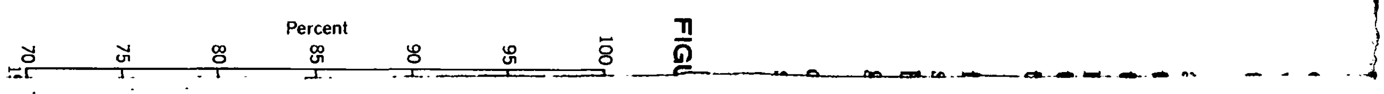
TABLE 3 Regression Results for Manufactured Goods Prices (Type II) with Alternative Measures of Capacity Utilization, 1955IV–1973IV

Eq.	Variant of Capacity Utilization	Constant	$\frac{AHE}{AHE(L)}$	$\frac{PR}{PR(L)}$	$\frac{1}{1-U}$	$\bar{R}^2$ [$\bar{S}$] {DW}
3.1	U	.1408 (2.11)	.6689 (9.69)	.1742 (15.51)	.00154 (4.66)	0.897 [0.00409] {1.53}
3.2	$\tilde{U}$	.1423 (2.16)	.6716 (9.83)	.1732 (15.55)	.00091 (4.85)	0.889 [0.00405] {1.53}
3.3	U_m	.3249 (4.66)	.5296 (7.68)	.1323 (10.26)	.00127 (5.99)	0.912 [0.00379] {1.36}
3.4	U'	.3050 (4.04)	.5290 (6.97)	.1478 (11.52)	.00224 (4.77)	0.898 [0.00406] {1.22}
3.5	$\tilde{U}'$	.3271 (4.70)	.5343 (7.81)	.1237 (9.00)	.00161 (6.05)	0.912 [0.00378] {1.36}

TABLE 4 Regression Results for Manufactured Goods Prices (Type II) with Alternative Measures of Capacity Utilization, 1955IV–1971III

Eq.	Variant of Capacity Utilization	Constant	$\frac{AHE}{AHE\,(L)}$	$\frac{PR}{PR\,(L)}$	$\frac{1}{1-U}$	$\bar{R}^2$ [$\bar{S}$] {DW}	*RMSE*, 1972–1973
4.1	U	.1458 (2.24)	.6917 (10.93)	.1471 (6.44)	.00140 (4.54)	0.792 [0.00362] {1.19}	.0076
4.2	$\tilde{U}$	.1385 (2.16)	.6992 (11.16)	.1497 (6.63)	.00081 (4.68)	0.795 [0.00359] {1.22}	.0073
4.3	U_m	.2934 (4.20)	.5674 (8.80)	.1172 (5.09)	.00113 (5.37)	0.811 [0.00345] {1.08}	.0064
4.4	U'	.2883 (3.85)	.5733 (8.15)	.1212 (5.01)	.00197 (4.57)	0.792 [0.00362] {2.94}	.0077
4.5	$\tilde{U}'$	.2892 (4.13)	.5787 (8.78)	.1173 (5.06)	.00148 (5.26)	0.809 [0.00347] {1.05}	.0057

RMSE = root-mean-square error.



FIG

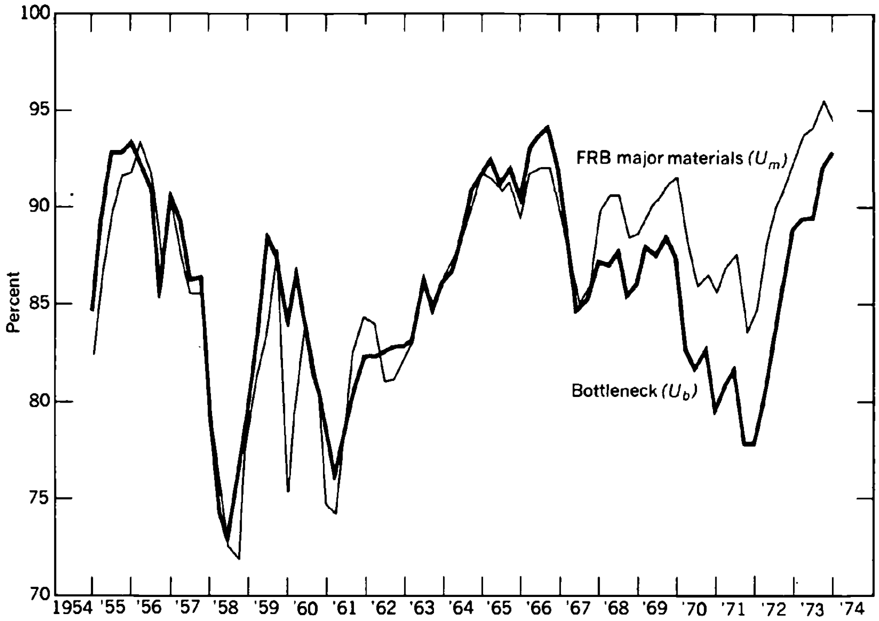
errors of the equation if examination is limited to the periods in which the level of utilization is relatively high and U_b is substantially above U: 1955IV–1957II, 1965I–1966IV, and 1972IV–1973IV.

For each of the equations in Table 3, truncated regressions were also run over the period 1955IV–1971III, thus ending just prior to the period of controls (see Table 4). In addition to the usual statistics, root-mean-square errors (*RMSE*) of prediction over the period 1972I–1973IV are also shown in the table. These are about the same for equations 4.1 and 4.2 as are the t ratios of the utilization terms.

When the Federal Reserve major materials index is substituted for U and $\tilde{U}$, however (equations 3.3 and 4.3), slightly better fits and substantially higher t ratios for the utilization term are obtained in both the full and truncated regressions. Substitution of U_m also gives a lower *RMSE* of prediction for the 1972–1973 period.

As noted earlier, U_m is conceptually most comparable to U_b (in contrast to U or $\tilde{U}$). The first two series are plotted in Figure 3. Very similar behavior in both level and movement is observed through 1967III (except during the steel strike of 1959, when U_m dips more

FIGURE 3 Utilization Rates: Bottleneck and Federal Reserve Board Major Materials, 1954IV–1973IV



sharply because of the larger weight of steel in the total). In 1967IV, however, U_m takes a large positive jump while U_b increases only moderately. Thereafter, the cyclical movements are roughly parallel, though until 1973 the gap between the two series gradually widens further.

This divergent behavior could be due either to differences in composition and weighting of components of the two series or to basic statistical differences in the component series themselves. The data in Table 5 are intended to shed some light on this question. For each of the U_m components (except steel) and for the most comparable components of the McGraw-Hill series, average utilization rates for the subperiods 1954IV–1967II and 1967IV–1973IV are shown. A consistent pattern of divergence is seen. Whereas most McGraw-Hill average rates either change little or decline somewhat from the first to the second subperiod, those for corresponding major materials components, except primary copper, increase. For petroleum refining, the major materials version shows a much sharper increase. This evidence strongly suggests that the divergence between the McGraw-Hill and major materials indexes after 1967 is statistically grounded.

The cause of the suddenness and persistence of this divergence is hard to pinpoint, particularly since the methods of data collection and construction are fundamentally very different. This behavior does roughly coincide with the onset of rapid growth of antipollution investment expenditures, much of which do not add to productive capacity or which may force early retirement of existing capacity. However, as Perry (1973, p. 721) observes, there is no reason to believe that the McGraw-Hill operating rate survey is biased on either ground "since it represents, ideally at least, a fresh assessment each year of the utilization of available capacity." Indeed, it is the major materials index that uses explicit capacity data from establishment surveys. But capacity is expressed in physical units of output rather than capital. Hence, there should be no bias from misrepresentation of antipollution investment here either.

Another possibility is that there was an increased dispersion of utilization rates among different kinds of output. This would tend to be hidden in the average utilization rates reported by multiproduct companies and to bias the bottleneck rate downward. It is hard to believe, however, that this change would have developed so abruptly.

We are thus left uncertain as to which series more accurately portrays the utilization rate of strategic manufacturing industries since the late 1960s. If the McGraw-Hill–based U_b is low for this

TABLE 5 Average Utilization Rate for Selected McGraw-Hill Industries and Corresponding FRB Major Materials Categories, 1954IV–1967III and 1967IV–1973IV (percent)

McGraw-Hill			FRB Major Materials		
Industry	1954IV–1967III	1967IV–1973IV	Industry	1954IV–1967III	1967IV–1973IV
Textiles	90.5	88.0	Broad woven fabric	85.4	87.5
			Yarn spinning	91.7	92.9
Paper and paper products	91.5	91.6	Wood pulp	88.4	92.8
			Paper	92.4	94.6
			Paperboard	87.3	94.4
Chemicals	81.0	80.4	Man-made fibers	81.0	87.4
Petroleum refining	90.3	93.8	Petroleum refining	87.3	94.9
Nonferrous metals	84.5	81.9	Primary copper	73.8	71.1
			Primary aluminum	91.4	94.3
Stone, clay, glass	80.4	79.2	Cement	79.9	82.0

period, there is also a strong presumption that U is low as well, since U_b is generally either above or about the same as U. We have the following (admittedly inconclusive) evidence that U and U_b are biased downward rather than that U_m is biased upward: (1) U_m performed better than U in the price equations. (2) There are anecdotal reports of capacity shortage during 1973, which is not evidenced by the McGraw-Hill series. (3) Still higher levels of utilization appear in the Wharton index for manufacturing as a whole than are shown for major materials.[18]

Proceeding on the *assumption* that U_m is a more accurate measure, we may use it to make a bias correction to U. We next construct a new bottleneck-weighted index ($\tilde{U}'$), using the bias-corrected U series (U') and U_m (in place of U_b). We then test whether $\tilde{U}'$ outperforms U' in the manufacturing price equation (as was expected for $\tilde{U}$ vis-à-vis U). Specifically, it is assumed that the bias correction for overall utilization (U) is the spread between U_m and U_b. Hence, by definition $U' = U + (U_m - U_b)$.

Next, the adjusted bottleneck-weighted index is derived as

$$\tilde{U}' = \begin{cases} \alpha' U' + (1 - \alpha')\, U_m, & U_m > U' \\ U', & U_m \leq U' \end{cases}$$

$$\alpha' = \exp\{-[0.04/(0.96 - U_m)]\}$$

Regressions 3.4 and 3.5 give results using U' and $\tilde{U}'$, respectively, for the whole period; and 4.4 and 4.5, for the truncated one. The adjusted bottleneck-weighted index does give better results than the (adjusted) ordinary index, especially in the longer regression (Table 3), which includes the critical 1973 observations. The *RMSE* of prediction in 1972–1973 (Table 4) is also substantially smaller. Note that the difference $\tilde{U}' - U'$ is virtually the same as the difference $\tilde{U} - U$; but the difference between the reciprocal complements of $\tilde{U}'$ and U' is substantially greater at the higher estimated levels of utilization than for corresponding $\tilde{U}$ and U values. Thus, incorporation of the bottleneck phenomenon, and not simply the higher level of U_m (compared to U and $\tilde{U}$) since 1967, accounts for improved performance.

The difference that incorporation of a bottleneck feature into measurement of capacity utilization makes in explaining inflation during high-capacity periods is indicated in Table 6, which contains results of dynamic predictions of manufactured goods prices made with the parameters of equation 3.5, using alternatively $1/(1 - U')$ and $1/(1 - \tilde{U}')$. Dynamic predictions cover the periods 1955IV–1957II, 1965I–1966IV, and 1972IV–1973IV. The table shows actual percent changes in price levels over each of the

TABLE 6 Actual and Predicted Changes in Manufactured Goods Prices for Selected Periods, Using $\tilde{U}'$ and U' of Equation 3.5[a] (percent)

	1955III–1957II	1964IV–1966IV	1972IV–1973IV
1. Actual	6.7	4.7	13.1
2. Predicted ($\tilde{U}'$)	5.1	5.4	12.8
3. Error (line 1 minus line 2)	1.6	−0.7	0.3
4. Predicted (U')	4.1	4.1	10.2
5. Error (line 1 minus line 4)	2.6	0.6	2.9
6. Difference (line 2 minus line 4)	1.0	1.3	2.6

[a] Predictions are "dynamic," i.e., predicted rather than actual values of lagged prices are used as they emerge in each period.

periods, predicted changes using each of the two utilization variants, the cumulative errors made in each case, and the difference between the predicted changes. The latter, apart from the overall equation error, indicates the contribution that the bottleneck element makes toward the explanation of inflation, given the estimated equation. In the first and third periods, inclusion of the bottleneck feature substantially reduces the equation error. In the 1972–1973 period, the equation error is small and the difference in predicted changes for the two utilization measures amounts to about one-fifth of the actual price increase.

V. INELASTIC AGGREGATE SUPPLY AND PRICE BEHAVIOR

So far, we have dealt with aggregate capacity measurement in relation to specific bottlenecks. We may think of the specific bottlenecks as constituting near bottlenecks for the economy as a whole: aggregate output is still capable of expanding, though only at higher marginal costs. We shall now briefly consider the case of perfectly inelastic short-run supply, i.e., where bottlenecks are sufficiently widespread to preclude any significant expansion of output whose mix approximates that observed when capacity is reached.

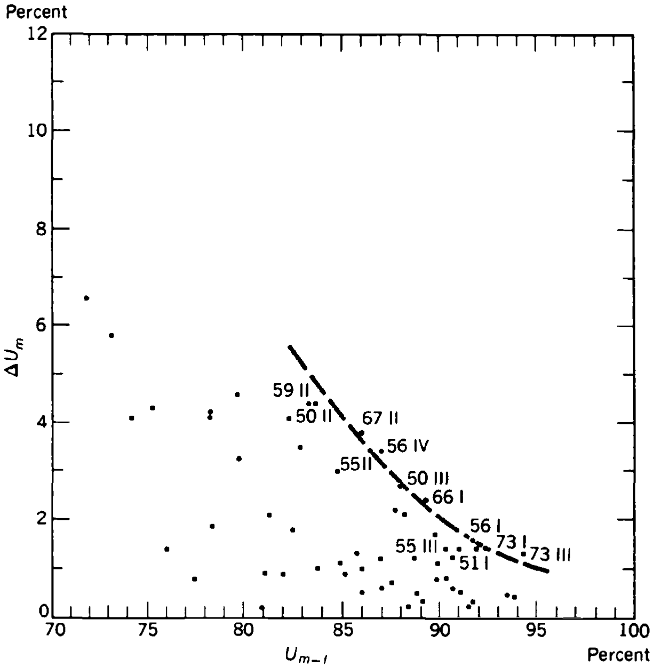
As noted in the introduction, such limits on aggregate output may occur with the measured utilization rate—ordinary or bottleneck-weighted—below 100 percent. This is because labor, delivery, or raw materials bottlenecks can occur as well as those in industrial plant and equipment capacity if growth of demand has been sharp. In this situation, measured capacity utilization—even a bottleneck-weighted variant—does not adequately reflect excess demand pressure.

In an earlier paper (Hirsch 1972) I developed a boundary condition on aggregate output for application to a macroeconometric model. More specifically, this boundary was defined in terms of maximum feasible growth of capacity utilization (as measured by the Wharton index) during any quarter, given the level of utilization during the previous quarter. A function defining the short-run capacity limit was determined on the basis of a scatter diagram, with ΔU plotted against U_{-1}. This boundary condition has the property that the permissible quarterly increase in utilization is less, the higher the level of utilization in the initial quarter. A procedure with a number of arbitrary, built-in rules was devised for adjusting the components of final demand to conform to constrained aggregate output and to raise prices above the levels of the unconstrained solution. Here we derive a similar supply-limit curve, though only for the more limited purpose of determining the possible existence of aggregate supply bottlenecks.[19]

Figure 4 is a scatter diagram of ΔU_m versus U_{m-1} (only positive changes in U_m are plotted). A dashed curve is drawn to fit the outermost points to suggest an approximate locus of upper limits of increase in utilization. In principle, no points should lie above the curve since, by definition of the limit, no such point is feasible; but by drawing the curve a bit lower, we allow for possible measurement error in the extreme (U_{m-1}, ΔU_m) pairs, and more points come close to the curve.

This diagram, together with equation 3.5, helps determine whether aggregate supply barriers contributed to inflation under tight capacity conditions. During 1955–1957 (U_{m-1}, ΔU_m) pairs are near the curve in four quarters: 1955II, 1955III, 1956I, and 1956II. Most of the residuals in equation 3.5 for the high-utilization period 1955IV–1957II are substantially positive, averaging 0.4 percent. During 1965–1966 only one quarter, 1966I, has a point near the curve. Two such quarters, 1973I and 1973III, occur during 1972IV–1973IV. However, the average residuals of 1965I–1966IV and 1972IV–1973IV are not substantially positive: inflation is essentially accounted for by the equation. Much of the 1973 increase is explained by raw materials prices. Thus, I conclude (tentatively) that short-run inelastic supply may well have contributed to inflation during 1955–1957, but not in later periods of high utilization.[20]

FIGURE 4 Change in Capacity Utilization Rate (ΔU_m) versus Lagged Level (U_{m-1})



SOURCE: Federal Reserve Board major materials index of utilization.

VI. SUMMARY AND CONCLUSIONS

This paper was concerned with one aspect of the more general (and difficult) problem of bringing supply factors within the realm of quantitative macroeconomic analysis. Specifically, balance of capital capacity among manufacturing industries was explicitly taken into account in deriving an aggregate index of capacity utilization. A "bottleneck-weighted" index of utilization was constructed in the belief that it would be more useful as a measure of excess demand than an index aggregated by orthodox weighting methods, especially during the boom phase of a business expansion when demand may well be pressing against capacity.

Initial tests of the modified utilization rate in the context of a price regression equation were disappointing in that they yielded essentially unchanged results compared to the ordinary utilization rate. Only when the two indexes were adjusted for assumed bias, with the Federal Reserve Board's major materials index used as auxiliary information, was there a noticeable improvement in the goodness of fit and statistical significance of the utilization variable. In periods of demand-pull inflation, the bottleneck weighting of the utilization rate (with the bias adjustment) generally reduces the equation error and in 1973 contributes substantially to the amount of total inflation accounted for.

Nonetheless, these findings must be regarded as both tenuous and tentative. First, all capacity utilization data are subject to great uncertainty, and the reciprocal complement form of the utilization variable makes it especially sensitive to errors of measurement. Second, available data on capacity utilization from surveys is broken down into subaggregates that are too broad to identify all important bottlenecks; bottlenecks should also be identified within multiproduct, multiple process industries, as was done by Malenbaum (1969) and Griffin (1971) in measuring capacity for chemicals and petroleum refining, respectively. Third, reporting of operating rates by company rather than by product gives rise to possible bias at the industry level. Fourth, there are relatively few observations for periods of strong demand-pull inflation, when bottlenecks are most likely to occur.

As noted, Perry (1973) has questioned the value of incorporating bottlenecks into an aggregate measure of capacity utilization, pointing out that shortages of labor and raw materials as well as of specific capital may occur and may also affect price behavior. From an aggregative point of view, the degree of capacity balance is clearly an essential consideration in determining available capacity. In this study it has been found (tentatively) that when bottlenecks are built into the utilization index, some improvement in price equations using such an index results. It is, of course, an empirical question—not investigated in this paper—whether a separate bottleneck variable in addition to the ordinary utilization rate would do better.

The problems of specific labor and materials shortages are not readily dealt with. It is not easy, for example, to see how analysis of the impact of the Arab oil embargo could be included as part of a general methodology.[21] This does not, however, vitiate the usefulness of the kind of effort pursued in this paper.

A methodology for defining a limit condition which determines absolute aggregate short-run supply inelasticity was briefly explained and applied to manufacturing capacity. Together with the residuals of the price equation (based on the bottleneck-weighted utilization rate), this provided evidence that aggregate supply limitations in manufacturing accounted for some of the inflation during the period 1955IV–1957II. Again, this conclusion must be regarded as tenuous, depending sensitively on the substantial degree of subjective judgment involved in establishing the limit condition. Here, too, more careful work needs to be done.

NOTES

1. It might be argued that this difficulty is circumvented by using new or unfilled orders, since, unlike output, these are not restricted by physical capacity. However, only a portion of output is produced in response to orders. Moreover, new orders may be delayed or cancelled when existing backlogs are already high.
2. The annual utilization survey conducted by McGraw-Hill (1972) has usually included such a question, and the newer BEA survey (SCB 1974b) regularly obtains such a figure from its respondents.
3. See Klein (1973) and Perry (1973). Klein implies that the Wharton index effectively deals with the problem via its trends-through-peaks approach for measuring capacity "because many or most industries peak approximately together" (p. 744). Perry, however, maintains that bottlenecks should be treated separately from the measurement of capacity utilization. I shall return to this question later.
4. Malenbaum, who studied the bulk organic chemical industry, measures capacity for each process in engineering terms, i.e., as maximum physical capacity. Aggregate capacity for the industry is derived by an LP solution to the problem of maximizing net output along the ray of the observed product mix, subject to input-output requirements, technologically determined joint product proportions, and (fixed) process capacities. Griffin's study (of petroleum refining) also involves process capacity; but aggregate capacity is determined by minimum average cost, which becomes the objective function of the LP model. Griffin analyzes both the fixed and variable mix cases, but the fixed mix used is an analytically derived one for full-employment demand rather than the observed mix.
5. The bottleneck problem in relation to capacity measurement is peculiarly a problem pertaining to price determination. It is not directly relevant, for example, to investment behavior, unless investment is a nonlinear function of the utilization rate. Then the dispersion of utilization rates as well as the aggregate level will matter.
6. The most recently published series is that of the Bureau of Economic Analysis (SCB 1974b); it is accompanied by a convenient synopsis of various measures of manufacturers' capacity utilization.
7. As Perry (1973, pp. 707–708) states: "A serious weakness of the FRB index is that benchmarking to the utilization survey is based on historical statistical relationships that are simple at best and that may change substantially. In particular, estimates for recent years are based on simple time trend estimates of

the drift that are heavily weighted with historical information. The estimates are not currently updated; and even if they were, they would still not adequately reflect any abrupt changes in the relation of investment and capital stock to capacity or in [a] bias in the McGraw-Hill capacity series."

8. This hypothesis is supported by a regression relating (implied) capacity, in log form, to output and capital stock. The null hypothesis of no cyclical reporting bias implies a zero elasticity of measured capacity with respect to output and an (approximately) unitary elasticity with respect to capital stock. Among the four series tested, only the McGraw-Hill utilization-derived capacity measure yielded a significant positive coefficient for output (Perry 1973, pp. 110–111).
9. The methodology for interpolation is as follows: Implicit capacity is measured for each year-end by dividing (industry and total manufacturing) operating rates into the respective component of the Federal Reserve industrial production index (IPI) for December. This is assumed to represent capacity output for the fourth quarter. Capacities for intervening quarters are obtained by interpolation on the assumption of a constant relative growth per quarter. Utilization rates for the first, second, and third quarters are then approximated by dividing, respectively, March, June, and September IPIs by corresponding interpolated capacities.
10. Preliminary regression tests using this series compared with the longer McGraw-Hill series indicated that the BEA sample is inadequate.
11. Input-output sectors were combined to correspond as closely as possible to the McGraw-Hill industrial categories. Separate utilization data for iron and steel ceased to be available after 1961. Therefore, from 1962I on, the basic steel component of the Federal Reserve's major materials index was linked to this series.
12. The discussion is couched, somewhat obscurely, in terms of the influence of the size of the capital stock on price.
13. Evans (1969, pp. 296–297), for example, obtains a variable markup model by assuming a cyclically variable elasticity of demand and profit-maximizing, imperfectly competitive firms. Variable demand elasticity can result from parallel shifting of the demand schedule, with marginal cost not necessarily rising. The form is $P = a_0 + a_1 ULC + a_2U + a_3\, \Theta(U)$, where P = price, ULC = unit labor cost, U = the utilization rate, and $\Theta(U)$ may or may not be linear, depending on the shape of the marginal cost schedule.
14. A variable of this form is used, in a level-form of price equation, in the BEA quarterly model (BEA 1973, sect. IX). The composite variable, along with level of capacity utilization, serves to vary the price markup over unit labor cost.
15. Nordhaus (1972) has criticized econometric price equations for not including capital costs along with labor and materials costs, noting their special relevance for target-return pricing. Only under certain assumptions on underlying production functions and pricing behavior can this omission be fully justified (see, e.g., Evans 1969, pp. 290–292; and Hymans 1972). This sin is perpetuated in the present paper because it was felt that omission of a (complex and hard-to-estimate) cost-of-capital variable does not interfere with the purpose of this section—to make comparisons among alternative concepts of capacity utilization.
16. The form $\Delta[1/(1 - U)]$, which can represent either nonlinearly rising marginal cost near full capacity or excess demand, was also tried, but never found to be significant. It is, of course, highly correlated with ΔU.
17. Similar equations with $\tilde{U}$ and U_m substituted for U in the excess demand terms

were also tried, since comparative results for different specifications might have been different; qualitatively, however, they were not.

18. One may conclude with Perry (1973, p. 731) that the Wharton methodology biases recent levels upward without rejecting the suggestion that perhaps other indexes, including McGraw-Hill's, ought to be higher.
19. U_m rather than U_b is used, since we are tentatively assuming that it more accurately represents a bottleneck utilization rate since 1967. It is also preferred to the bottleneck-weighted index U' because rapid increases in the latter may reflect a shift in weighting from U' toward U_m instead of (or as well as) actual increases in utilization rates.
20. Note the contrast between this accounting for the 1955–1957 inflation and the well-known demand-mix explanation given by Charles Schultze in 1959.
21. In the manufacturing price equations, at least the pass-through of higher oil prices should be captured in the raw materials price variable.

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COMMENTS

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The concepts of industrial capacity and capacity utilization are central to many areas of modern economic analysis. Yet, despite numerous attempts to measure these concepts, involving many different approaches, the measures available to us are far from adequate. As a result, the ingenuity of economists is repeatedly tested when they try to make good use of the information on industrial capacity that is available. Albert Hirsch's paper is the latest example of ingenuity applied to those data.

The two main uses of capacity data by economists are in estimating investment demand and price behavior. Hirsch is concerned with the latter of these. He argues that capacity utilization is likely to be most important for price determination when utilization rates are near effective capacity and supply bottlenecks are likely to appear. Accordingly, he develops a "bottleneck-weighted" index of capacity utilization in manufacturing as a means of capturing the special effects of such supply conditions.

Hirsch rejects as unrealistic the rigid notion of supply bottlenecks implied by an input-output approach. The existence of inventories and of imports and substitution possibilities by both producers and consumers make it unlikely that capacity limits in any one industry can have overriding importance for the pricing of industrial output as a whole. He thus adopts a pragmatic approach to measuring bottleneck effects by forming an index in which utilization rates of all industries enter, but with weights that depend on two characteristics of special importance for price determination. The first is the proportion of an industry's output that is an intermediate product utilized by other industries; the second is a nonlinear measure of how near an industry is to its capacity ceiling. Thus, in his measure, an important primary or intermediate processing industry with operating rates at or near peak levels would receive a disproportionately large weight in the measure of aggregate supply conditions. There is no way to test the particular formulation that Hirsch devised, but it looks sensible and captures the effects that he expects should be important.

Over the business cycle, the bottleneck-weighted measure of utilization that Hirsch calculates has the properties one would expect relative to conventional utilization measures. It shows tighter supply conditions than are revealed by conventional measures of utilization in the neighborhood of most business cycle peaks. However, when predictive ability in price equations for manufacturing is compared, there is little to distinguish the bottleneck-weighted index from the conventional utilization measure. He sets out to see what might account for this, and, although his procedure may seem to be excessively ad hoc, I think he is probably on the right track. In the basic utilization series from which he forms his bottleneck index, the degree of utilization in some primary industries was apparently understated in recent years. He cites the new Federal Reserve index of operating rates in major materials industries as some evidence for this and uses the major materials index to adjust both the conventional and the bottleneck-weighted utilization series for bias in recent years. These bias-corrected versions do give a clear verdict in favor of the bottleneck-weighted concept when the corrected series are compared in price equations.

In a later section of his paper, Hirsch specifically looks for speed-limit effects by examining whether price underpredictions are exceptionally large in years when utilization rates are already high and become abruptly higher. He concludes that such effects—which he refers to as short-run inelastic supply situations—were important only in the mid-1950s and not in later inflationary periods. I wish he had pursued this question further. If capacity utilization is already at high levels, it may be difficult to push it still higher, even though demand is growing very rapidly and short-run excess demand problems exist. Hirsch himself had offered this observation earlier in his paper, when he noted that any measure will be an ex post reading of capacity actually utilized.

One wrinkle that Hirsch might have added to his analysis would be a weighting of individual industries that took account of how sensitive their prices were to their own utilization rates. There is some evidence on this sensitivity for industries at different levels of aggregation, and it shows that utilization rates are far more important for pricing in some industries than in others. Indeed, the automobile industry offers an example of pricing behavior that, historically, is inversely related to the degree of capacity utilization. Hirsch's bottleneck concept probably offers a better measure of price pressures than is available from aggregate utilization rates. However, if refined with some allowance for price sensitivity in individual industries, it might be considerably improved.