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ON THE ECONOMIC INTERPRETATION AND MEASUREMENT OF OPTIMAL CAPACITY UTILIZATION WITH ANTICIPATORY EXPECTATIONS

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ABSTRACT

This study builds on recent research giving the notion of capacity utilization clearer economic foundations. In this research optimal output Y* is defined as the minimum point on the firm's short-run average total cost curve, and capacity utilization is then computed as CU=Y/Y*, where Y is actual output. Here I extend these concepts to include adjustment costs due to changes in the stock of capital, and nonstatic expectations of future output demand and input prices. The more general notion of CU is shown to depend on the shadow values of the firm's quasi-fixed inputs, and is decomposed to isolate the effects of anticipatory expectations. An empirical comparison is then made between traditional indices and alternative economic CU measures, using annual U.S. manufacturing data 1954-80. The calculated indices exhibit plausible patterns, which can be interpreted as the effects of nonstatic expectations and adjustment costs.

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I. Introduction

The rate of capacity utilization is a very common index of cyclical variation. Several measures of capacity utilization (hereafter, CU) exist, mostly based on peak-to-peak interpolation or survey information. Until recently, turning points of these CU measures tended to correspond closely to other typical cyclical indicators such as labor productivity and Tobin's q. However, since the 1973 energy price shocks the various measures have increased in volatility, and although still procyclical, they have not exhibited the strong interrelationships observed earlier. This raises the issue of whether past relationships among these indicators still hold. Such a question is, however, difficult to answer with traditional cyclical measures, since for the most part they are not based on an explicit economic structure.

In this paper I demonstrate that movements in certain cyclical measures -- particularly capacity utilization -- are not random but can be viewed as systematic results of a rational economic optimization process undertaken by the firm, characterized by the type of general dynamic optimization framework discussed in Morrison (1982). Specifically, I develop a general approach for determining an economic CU measure that is closely related to the shadow value of fixed inputs such as capital. Since these measures are calculated within an economic optimization framework, they depend explicitly on the existing economic structure and exogenous variables. Hence they provide more useful interpretable information than is generated by traditional measures.

The CU measure is related to the notion of capacity output Y^* discussed earlier by Cassels (1937), B. Hickman (1964) and others, and defined as the level of output which minimizes short run average total costs (SRAC). The CU ratio is then defined as Y/Y*, where Y is observed output. Trends in CU reflect variations in utilization of the firm's quasi-fixed inputs such as capital. This suggests a close theoretical relationship with investment analysis and thus Tobin's q, as well as with single-factor productivity indicators such as that for labor.

Static models cannot adequately explain these cyclical phenomena, because they do not recognize the importance of gradual movements in input stocks. Dynamic models, however, are useful since they are based on costs of adjustment for quasi-fixed inputs that induce slow adjustment by firms to "optimal" or "desired" levels of the quasi-fixed inputs. Within a dynamic framework, firms move along a given short run average total cost (SRAC) curve, and also shift their SRAC curves by optimally investing in quasi-fixed inputs. This dynamic optimizing behavior has implications for movements in CU since Y* is determined by the position of the SRAC curve.

The principal goals of this paper are therefore (i) to develop a conceptual framework for understanding cyclical movements in CU, and (ii) to illustrate these phenomena empirically by providing econometric estimates based on alternative CU specifications. I proceed as follows. In Section II, generalizing from a dynamic model in the tradition of Lucas (1967), Treadway (1970), Fuss (1976), Berndt, Fuss and Waverman (1979) and Morrison and Berndt (1981), I graphically consider how alternative assumptions about expectations formation and other structural phenomena have differing implications for CU measurement. In Section III I provide further interpretation by developing a more formal analytical derivation of the model. In Section IV I illustrate these results empirically, Finally, in Section V I present concluding remarks.

II. A Diagrammatic Analysis of CU with Static and Nonstatic Expectations

The geometric representation of CU with static expectations is straightforward. Following Morrison and Berndt (1981) (hereafter M-B), assume that the firm's technology can be represented by a quadratic normalized variable cost function G with long run constant returns to scale,

$$(2.1)\qquad G=L+P_E E+P_M M = Y(\alpha_0+\alpha_{0t}t+\alpha_E P_E+\alpha_M P_M+.5(\gamma_{EE}P_E^2+\gamma_{MM}P_M^2)+\gamma_{EM}P_E P_M$$
$$+\alpha_{Et}P_E t+\alpha_{Mt}P_M t)+\alpha_K K+.5(\gamma_{KK}K^2/Y)+\gamma_{\dot{K}\dot{K}}(\dot{K}^2/Y))+\gamma_{EK}P_E K+\gamma_{MK}P_M K+\alpha_{Kt}Kt\ ,$$

where capital (K) is the quasi-fixed input, labor (L), energy (E), and non-energy materials (M) are variable inputs, P_E and P_M are corresponding variable input prices normalized by P_L, and where net investment ($\dot{K}$) incorporates internal costs of adjustment.

Within this framework, one can specify how Y* (that level of output at which SRAC is minimized) is affected by changes in exogenous variables. Specifically, Y* can be derived explicitly by differentiating average total costs (average variable costs plus average fixed costs) with respect to Y and solving for Y* as the minimum point on this SRAC curve (see Figure 1). This yields

$$(2.2)\qquad Y^* = Y^*(K,\dot{K},P_j,u_K,t)$$
$$= -(\gamma_{KK}K^2 + \gamma_{\dot{K}\dot{K}}\dot{K}^2)/(\alpha_K K + \alpha_{Kt}K\cdot t + \gamma_{EK}P_E\cdot K + \gamma_{MK}P_M\cdot K + u_K K),$$

which results in the capacity utilization measure

$$(2.3)\qquad CU = -Y(\alpha_K K + \alpha_{Kt}K\cdot t + \gamma_{EK}P_E\cdot K + \gamma_{MK}P_m\cdot K + u_K K)/(\gamma_{KK}K^2 + \gamma_{\dot{K}\dot{K}}\dot{K}^2),$$

where u_K is the (normalized) one period user cost of capital services. Note that changes in exogenous input prices can shift the SRAC to the right (increasing Y*), to the left (decreasing Y*), or upward (without affecting Y*).

Under the assumption of static expectations, the above CU measure has been derived and estimated by Berndt, Morrison and Watkins (1981) and Berndt (1980). An interesting feature of their empirical results is that while the CU measure has plausible directional changes, it is always greater than one, implying that actual output Y is always greater than Y*, as in Figure 1. This is consistent with a perennial capacity shortage in that it is always optimal to reduce unit costs by increasing K. Such a curious result could be due to failure to account for nonstatic expectations, since with no forward-looking expectations the growing firm is always behind in capital stock formation, resulting in perpetually observed "catch-up" investment. This illustrates the dependence of CU measurement on assumptions concerning expectations formation.

In order to analyze the effects of nonstatic expectations diagramatically, it is useful first to comment on why investment occurs. At an equilibrium point, the firm's capital shadow valuation (its net value in terms of reduced variable costs) equals the exogenous market rental price of capital u_K. Suppose, however, that output demand increased. In such a case, due to the increased potential profitability of an incremental unit of K, the shadow value of K (hereafter, Z_K) would exceed u_K. Thus, in maximizing the present value of long run profits, the firm would face incentives to increase investment, shifting its SRAC curve to the right until the new Z_K equalled u_K.

Now consider the case of certain but nonstatic expectations. In order to determine its optimal current investment, the firm must take into

Figure 1

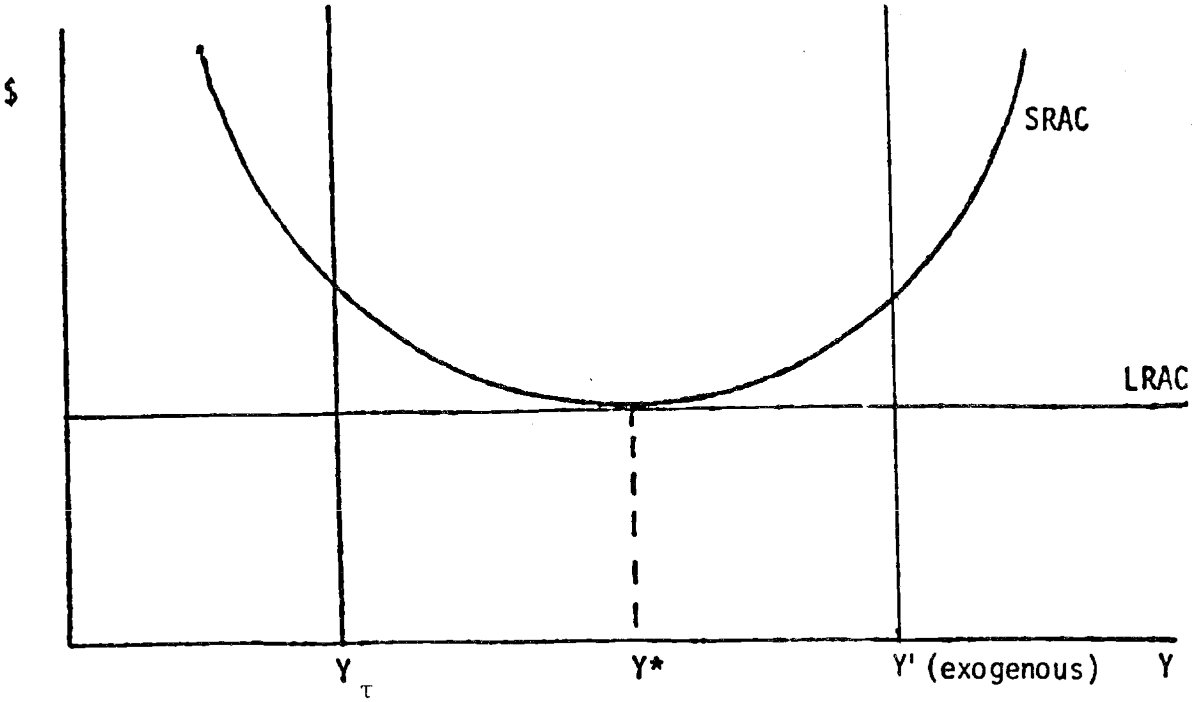
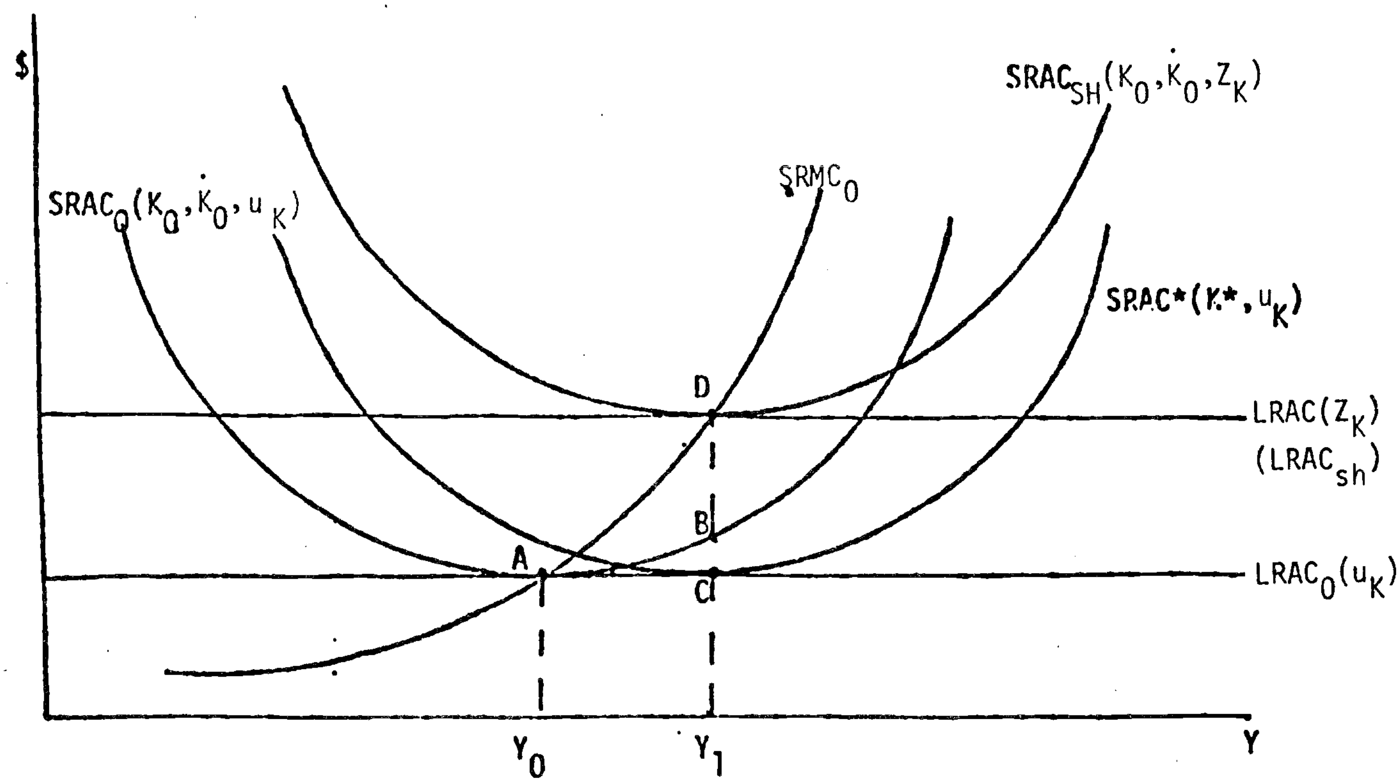


Figure 2



consideration the entire future time paths of exogenous variables such as input prices, output or demand. As a very simple example, consider a cost-minimizing firm at time t_0 expecting with perfect certainty a permanent upward shift in market output demand at time t_1, with all other exogenous variables remaining constant for all time. Denote the optimal long-run capital stock under increased output demand as K^*_1. With no adjustment costs, K would increase from K^*_0 (corresponding to the original demand curve) to K^*_1 instantaneously at time t_1, implying an infinite rate of investment at that time. With adjustment costs, however, the demand shift would not be accommodated as quickly. Rather, the firm's investment rate will increase immediately from that rate optimal under static expectations for all exogenous variables, to a larger current rate for all time periods τ, $t_0 < \tau < t_1$. Hence, unlike static expectations, where the adjustment process would commence at t_1, anticipatory expectations imply that the firm will approach K^*_1 gradually, beginning at t_0.

An implication is that in such a case optimal current investment for all τ, $t_0 < \tau < t_1$, is greater than the optimal investment based only on currently observed exogenous variables. Further, the present value of incremental current expenses associated with increased current investment would be less than the present value costs associated with the accelerated investment at t_1 required if there were no anticipation of the demand shift; in terms of present value optimization the firm benefits from correctly expecting the exogenous demand shift.[1]

The above discussion illustrates a point on intertemporal optimization and "desired" capital stocks made by Nickell (1978):

> "...instead of the firm aiming at a simple 'desired' capital stock K*, it aims at the desired capital stock for the next period plus an exponential weighted sum of the difference between the desired capital stock next period and the different desired capital stocks for all future periods."

Morrison (1983a) has developed Nickell's notion further, and has derived the corresponding investment equation having the form:

$$(2.4)\quad I(t)=\lambda K(t)-\lambda K^*(t)+(1/G_{\dot{K}\dot{K}})\int_t^{\infty} e^{(\lambda-r)(s-t)}((G_{KK}+rG_{\dot{K}K})((K^*(s)-K^*(t))+G_{\dot{K}P}P(s) + G_{\dot{K}Y}Y(S))$$

where $K^*(s)$ is the "desired" capital stock defined for prices and demand levels at time s, $Y(s)$ is expected output, r is the constant real rate of return, P is a vector of expected input prices, G_{ij} are the second partial derivatives of the quadratic cost function (2.1), and λ is the partial adjustment parameter.

It is clear from (2.4) that if all exogenous variables were expected to be constant, $K^*(s)=K^*(t)=K^*$, implying that (2.4) would reduce to the standard flexible accelerator model. In general, however, while the current optimal capital stock is given by $K^*(t)$, the present value-maximizing "target" stock level is $K^{**}(t)=K^*(t)+J(t)$, where $J(t)$ represents the incremental current capital stock due to anticipatory expectations.

The terms of shadow values, given an anticipated output demand increase, the shadow value of capital Z_K at t_0 is equal to the current static marginal value given all exogenous variables, plus the possible extra discounted net revenue provided by the incremental demand at t_1. Thus Z_K at time t_0 is larger with anticipatory than with static expectations, consistent with a difference between K^{**} and K^* and encouraging extra anticipatory investment between t_0 and t_1. Conversely, if reductions in future output demand were anticipated, Z_K based on nonstatic expectations would be smaller than that based on static expectations.

With anticipatory investment behavior, therefore, the firm's SRAC curve and its corresponding optimal capacity output and implied CU ratio will differ from that based on static expectations. To consider CU derivation with anticipatory expectations, assume that before time t_0 the firm was in long run equilibrium with exogenous Y equal to capacity output Y*. Then, as above, at time t_0 the firm learns that at t_1 output demand will increase. Because of the induced additional investment at all τ, $t_0 < \tau < t_1$, the new current capital stock will position a SRAC curve at time τ which reaches a minimum to the right of the current exogenous output level, Y_τ (see Figure 1).

Since the current-valued diagram indicates $Y_\tau < Y^*$, there appears to be current excess capacity with an associated CU rate of less than unity. However, the position of the SRAC curve in such a case reflects results of a present value optimizing decision, and thus the current exogenous output Y_τ must in a present value sense be optimal. This demonstrates that a current measure of CU may diverge from unity in the short run even when the firm is at a true intertemporal optimum.

The definition of the relevant CU measure in this case is not immediately clear. If capacity output Y** were defined in present value terms to reflect the future path of output levels, then with perfect expectations Y** and Y_τ would always coincide, and CU would always be unity. In such a case the difference between Y_τ and Y* would be interpreted as representing the impact on capacity output of nonstatic expectations. This is in direct contrast to the case of static expectations, where any divergence between Y_τ and Y* cannot be entirely attributed to previous shocks that were not expected and thus must be accommodated *ex post*.

Complexities arise when anticipatory expectations are imperfect. In such cases, the divergence between Y_τ and Y^* cannot be entirely attributed to the effects of perfect anticipatory expectations. Instead, a portion of this divergence could be attributed to previous errors in expectations, analogous to the static expectations case where an unanticipated change occurs.

In addition, the above example is highly stylized with one permanent shock in one exogenous variable. In reality the paths of several exogenous variables will be changing over time, and not all changes will be permanent. This greatly complicates the analysis.

While such multiple influences cause interpretation of actual observed CU measures to be ambiguous, in the next section I show that it is possible in general to isolate the effect on capacity output of investment toward K^{**} rather than toward K^*. This facilitates interpretation of, for example, low current-valued CU measures in terms of whether they are due to optimistic anticipatory investment behavior or inadequate levels of current output demand.

III. CU Measurement: Further Analysis

The discussion in the previous section considered CU measurement under simplified assumptions. In order to generalize the analysis, it is useful to introduce the notion of the firm's shadow cost function.[2] The shadow cost function is simply the total cost function with the contribution of capital assessed at its shadow value Z_K rather than at its market value u_K. I first consider the case of static expectations and constant returns to scale.

Given the normalized cost function G, the shadow cost function can be characterized by

(3.1) $G(Y,P_i,t,K,\dot{K}) + Z_K K,$

where K is the current level of capital. Assuming adjustment costs occur only for net investment, and that G is a "static" short run cost function without K, Lau (1976) has shown that the shadow value equals the negative of the partial derivative of G with respect to K, denoted $-G_K$.

In the case discussed here, where the dynamics of the firm's behavior are represented by $\dot{K}$ in the variable cost function, the contribution of $\dot{K}$ must also be recognized. More specifically, the shadow value of K must include not only the reduction in variable costs associated with one more unit of capital, but also the cost of putting the capital in place -- the increased cost of investment. This "net" shadow value $Z_K K = -(G_K K + G_{\dot{K}} \dot{K})$ is similar to the notion of marginal efficiency of investment, whereas the "gross" shadow value of $Z_K K = -G_K K$ more closely represents the marginal efficiency of capital. Note also that in temporary equilibrium $\dot{K} \neq 0$; $\dot{K}$ must be taken into account in the derivation of CU since it is incorporated into the SRAC curve. Thus (3.1) becomes

(3.2) $G(Y,P_i,t,K,\dot{K}) - G_K K - G_{\dot{K}} \dot{K}.$

An interesting feature of the shadow cost function is that with long run CRTS, the firm is always producing at the minimum of the short run average shadow cost (hereafter, $SRAC_{SH}$) curve, simply because this curve characterizes a notional long run equilibrium where Z_K is the effective "price" of K. Thus the deviation of shadow from total costs characterizes the divergence between temporary and long run equilibrium. If shadow costs are set equal to total costs, the minima of the two corresponding average cost functions are forced to coincide, and there will be no incentive for the firm to move from that point. The equilibrium condition for the firm can be restated, given this interpretation, as

$$(3.3) \qquad G(\cdot) - G_K K - G_{\dot{K}} \dot{K} = G(\cdot) + u_K K \quad \text{or} \quad -(G_K K + G_{\dot{K}} \dot{K}) = u_K.$$

Since (3.3) imposes long run equilibrium, it can characterize the stationary point alternatively as (i) the optimal K* level given Y, or (ii) the capacity Y* level given K.

The above procedure for deriving Y* as that level of Y which sets $u_K K = -(G_K K + G_{\dot{K}} \dot{K})K$ differs from that noted at the beginning of Section II, where Y* was defined as the output level at which SRAC was minimized. It is easy, however, to demonstrate their equivalence. Using the form for G from (2.1) and imposing $-(G_K K + G_{\dot{K}} \dot{K}) = u_K K$, results in

$$(3.4) \qquad -(\alpha_K + \gamma_{EK} P_E + \gamma_{MK} P_M + \alpha_{Kt} t + \gamma_{KK}(K/Y))K - \gamma_{\dot{K}\dot{K}}(\dot{K}^2/Y) = u_K K, \text{ implying}$$

$$(3.5) \qquad Y^* = -(\gamma_{KK} K^2 + \gamma_{\dot{K}\dot{K}} \dot{K}^2)/(\alpha_K + \gamma_{EK} P_E + \gamma_{MK} P_M + \alpha_{Kt} t + u_K K).$$

Hence it is clear that Y* in (3.5) equals Y* from (2.2).

This geometric interpretation of Y* is illustrated in Figure II. Assume the firm is at a temporary equilibrium position at point B with short run increasing average costs characterized by $SRAC_0(K_0, \dot{K}_0, u_K)$ and output Y_1; let the associated LRAC curve be $LRAC_0$. As a consequence of, say, a previous unexpected increase in exogenous output demand, Y_1 is larger than the output level Y_0 corresponding to the minimum point on the current $SRAC_0$ curve. Respecifying the total cost curve in terms of the shadow value of K, given K_0, $\dot{K}_0$, and Y_0, repositions the "effective" curve as $SRAC_{SH}$. Since Z_K exceeds u_K, capital is a binding constraint and more capital and investment is desired to reach $SRAC^*(K^*,u_K)$.

Recall that if one imposes the equilibrium adjustment condition $u_K K = -(G_K K + G_{\dot{K}} \dot{K})$, either K or Y could be adjusted. If K were allowed to adjust to the implied value consistent with a given steady state Y_1 level, K* could be determined simply as that amount of K at which the new, lower $SRAC_{SH}$ curve would be tangent with $LRAC_0$ at Y_1 (see point C on Figure II), thereby defining $SRAC^*(K^*,u_K)$. Obviously at point C the CU ratio is unity. If, however, K were held fixed at K_0 and output were altered to equate $u_K K$ and $-(G_K K + G_{\dot{K}} \dot{K})$, the firm's production level would decline from Y_1 to Y_0, and costs would fall as the firm "slid" back along the $SRMC_0$ curve from D until they reached the tangency with $LRAC_0$ at point A. Again, at A output Y_0 would equal Y*, CU=1, and there would be no incentive for the firm to alter its behavior.

A useful adaptation of this structure is to relax the assumption of CRTS. Under nonconstant returns to scale (hereafter, NCRTS), capacity output Y*, defined as that level of output at which short-run and long-run average cost curves are tangent, no longer occurs at the minimum point of the SRAC curve. Derivation of Y* from the shadow cost relationship (3.6) is, however, straightforward and analogous to that outlined above.

I now can construct the CU representations alluded to in Section II. Recall that with anticipatory investment K* in general differs from K**. Now denote the capacity output level corresponding with investment toward K** as Y**; when the corresponding $\dot{K}$ calculation is purged of the anticipatory behavior J (see 2.4)) the resulting Y* can be compared with Y** to delineate the impact of nonstatic expectations.

I illustrate Y** derivation with nonstatic expectations and NCRTS using the quadratic form for G, as in Morrison (1982),

$$(3.7)\qquad G = L + P_E E + P_M M = (\alpha_0 + \alpha_{0t} t + \alpha_E P_E + \alpha_M P_M + \alpha_Y Y)$$

$$+ \frac{1}{2}(\gamma_{EE} P_E^{\,2} + \gamma_{MM} P_M^{\,2}) + \gamma_{EM} P_E P_M + \gamma_{EY} P_E Y + \gamma_{MY} P_{MY}$$

$$+ \alpha_{Et} P_E t + \alpha_{Mt} P_M t) Y + \alpha_K K + \alpha_{\dot{K}} \dot{K} + .5(\gamma_{KK} K^2 + \gamma_{\dot{K}\dot{K}} \dot{K}^2)$$

$$+ \gamma_{EK} P_E K + \gamma_{MK} P_M K + \gamma_{YK} YK + \gamma_{E\dot{K}} P_E \dot{K} + \gamma_{M\dot{K}} P_M \dot{K}$$

$$+ \gamma_{Y\dot{K}} Y\dot{K} + \gamma_{K\dot{K}} K\dot{K} + \alpha_{Kt} K\cdot t + \alpha_{\dot{K}t} K\cdot t.$$

The Y** measure based on investment toward K** can then be calculated as

$$(3.8)\qquad (G_K K + G_{\dot{K}} \dot{K}) + u_K K = 0 =$$

$$(\alpha_K + \gamma_{KK} K + \gamma_{EK} P_E + \gamma_{EK} P_M + \alpha_{Kt} t + \gamma_{YK} Y + \gamma_{K\dot{K}} \dot{K} + u_K) K +$$

$$(\alpha_{\dot{K}} + \gamma_{K\dot{K}} K + \gamma_{E\dot{K}} P_E + \gamma_{E\dot{K}} P_M + \alpha_{\dot{K}t} t + \gamma_{Y\dot{K}} Y + \gamma_{\dot{K}\dot{K}} K)\dot{K}, \text{ or,}$$

$$(3.9)\qquad Y^{**} = (-(\alpha_K + \gamma_{KK} K + \gamma_{EK} P_E + \gamma_{EK} P_M + \alpha_{Kt} t + \gamma_{K\dot{K}} \dot{K} + u_K) K +$$

$$(\alpha_K + \gamma_{K\dot{K}} K + \gamma_{E\dot{K}} P_E + \gamma_{E\dot{K}} P_M + \alpha_{\dot{K}t} t + \gamma_{\dot{K}\dot{K}} K)\dot{K}/(\gamma_{YK} + \gamma_{Y\dot{K}}).$$

Thus, the relevant CU measure accounting for intertemporal optimization and anticipatory expectations involves comparison of actual output Y with Y**; the effect of anticipatory expectations can then be isolated by comparing the resulting CU measure to Y/Y*.

This characterization of capacity output Y** incorporating nonstatic expectations provides the framework for empirical analysis and measurement of alternative CU indices which are discussed in the following section.

IV. Empirical Illustration

In this section I present empirical illustrations of alternative annual CU measures for U.S. manufacturing, 1954-80.[3] A dynamic factor demand model based on the quadratic normalized variable cost function (3.7) with NCRTS was estimated under three alternative assumptions concerning expectations formations for input prices and output quantity: (i) static expectations, (ii) adaptive expectations, and (iii) general expectations, the last of which is less restrictive than (ii) and is consistent with "partial rationality." Additional details on the estimation and specification of these various models can be found in Morrison (1982 or 1983a).

Given the parameter estimates from these models, a number of alternative CU measures have been calculated from (3.9). First, as alluded to in the previous section, the calculation of capacity output is affected by whether the model is based on static or dynamic optimization. Inclusion of $G_{\dot{K}}\dot{K}$ reduces the "gross shadow value" of the capital stock $-G_K K$ to a "net" shadow value $-(G_K K + G_{\dot{K}}\dot{K})$, which incorporates the dynamic or flow nature of the firm's adjustment problem -- the costs incurred by moving to a new level of capacity. Thus, the corresponding net CU measure CU^n (based on the net shadow value of K) is likely to be closer to unity than the gross CU measure CU^g (based on the gross shadow value of K). The deviation between CU^n and CU^g isolates the impact of the dynamics of the model -- the adjustment costs -- on CU measurement, and therefore provides a basis for useful comparison.

Second, the effects of anticipatory behavior in the nonstatic expectations models is identified by comparing the CU measure based on predicted anticipatory investment toward K** (Y/Y**, denoted CU_{CV}) with that based on predicted investment were expectations static and were the capital "target" K* rather than K** (Y/Y*, denoted CU_{PV}). As postulated in the previous section, in an expanding economy current investment including that based on anticipated changes in exogenous variables would likely be greater than that warranted by current-valued variables, resulting in a CU_{CV} measure below unity even if present value optimization behavior is correct. The impact of anticipatory behavior is purged from the CU_{PV} calculation. CU_{PV} should therefore be closer to unity than CU_{CV}, since behavior which is not based on currently observed conditions is not attributed to current exogenous variables. Deviations in CU_{PV} from unity are interpreted as being due to the effects of discrepancies between previous expected and realized exogenous variables rather than to optimal forward-looking behavior.

In Table 1 I present four alternative series that in various ways replicate current known procedures for calculating CU. Specifically, in the first two columns I present traditional, mechanical CU measures as computed by the Federal Reserve Board (FRB, column 1) and Wharton (column 2). Both measures exhibit annual values whose level is always less than unity. Both show drops in the recessionary years of 1958, 1960-61, 1970-71, and 1974-75, and increases in subsequent years. The FRB measure is highest in 1966, while Wharton peaks in 1973; other "strong" years for FRB include 1955 and 1973, and correspondingly good years for Wharton are 1955 and 1969. The differences between Wharton and FRB indices are nontrivial; the simple correlation between them over this time period is only .605, suggesting that further analysis could be useful.

In columns three and four of Table 1 I present alternative economic measures of CU based on static expectations; the CU^n measure in column 3 is computed following the procedures of Berndt, Morrison, and Watkins, while the CU^g measure in column 4 ignores costs of investment in the shadow value of $Z_K K$.

A number of patterns in Table 1 are worth noting. First, as expected, CU^g tends to exceed CU^n. The difference between CU^n and CU^g is, however, relatively small, indicating only a marginal impact of adjustment costs on observed capacity utilization. The difference in levels is largest in the strong investment years of 1965 and 1966 when adjustment costs were largest, but the trends are analogous and reflect the peaks and troughs represented by the traditional measures. Both CU^n and CU^g exceed unity for most of the sample period, implying a current shortage of capacity. This tendency is, however, not as pervasive for CU^n as for indices based on earlier data sets, such as those reported in Berndt, Morrison, and Watkins [1981].

As was noted earlier, this predominance of large CU measures may partially reflect neglect of the impact of anticipated future paths of exogenous variables on the firm's current investment behavior. To assess this conjecture further, in Table 2 I present CU estimates based on two alternative expectations assumptions -- adaptive and general nonstatic expectations. Only CU^n estimates are reported since CU^n is the measure consistent with the dynamic model specification and since the relationship between CU^g and CU^n for the nonstatic expectations formulations is closely analogous to that discussed for the static expectations model. The entries in columns 1 and 2 are CU^n_{CV} and CU^n_{PV} for adaptive expectations, while those in columns 3 and 4 are CU^n_{CV} and CU^n_{PV} for general nonstatic expectations, respectively.

Table 1

Capacity Utilization Indices
Static Expectations Specifications, 1954-80
and Conventional Measures

Year	FRB (manuf.)	Wharton (manuf.)	CU^n_{CV}	CU^g_{CV}
1954	.803	.882	.991	1.001
1955	.871	.906	.981	1.013
1956	.864	.879	1.009	1.040
1957	.837	.840	1.063	1.063
1958	.752	.741	1.017	1.017
1959	.819	.789	1.050	1.054
1960	.802	.768	1.119	1.124
1961	.774	.737	1.103	1.113
1962	.816	.765	1.157	1.179
1963	.835	.776	1.126	1.169
1964	.856	.795	1.071	1.160
1965	.896	.842	1.020	1.140
1966	.911	.882	1.034	1.130
1967	.869	.869	1.081	1.121
1968	.871	.891	1.055	1.087
1969	.862	.900	1.088	1.105
1970	.793	.838	1.045	1.047
1971	.784	.823	1.008	1.015
1972	.835	.875	1.069	1.086
1973	.876	.926	1.075	1.122
1974	.838	.898	1.119	1.141
1975	.729	.789	.984	.994
1976	.795	.849	1.000	1.021
1977	.819	.874	1.029	1.058
1978	.844	.901	.987	1.037
1979	.857	.917	.949	1.005
1980	.791	.858	.882	.917
r_{FED}	-	.619	.135	.456
r_{WHAR}	.619	-	.349	.195

Table 2

Capacity Utilization Indices, CU^n
General and Adaptive Expectations, 1954-80

Year	CU^n_{PV} (adap)	CU^n_{PV} (adap)	CU^n_{CV} (general)	CU^n_{PV} (general)
1954	.804	.936	.803	.968
1955	.867	.973	.844	.987
1956	.852	.968	.766	.978
1957	.947	.974	.852	.980
1958	.854	.926	.788	.954
1959	.943	.977	.922	.988
1960	.968	.990	.902	.990
1961	.918	.978	.874	.986
1962	.985	1.009	.920	.998
1963	.952	1.013	.930	1.001
1964	.887	1.012	.915	1.002
1965	.863	1.017	.888	1.002
1966	.877	1.014	.847	1.001
1967	.930	1.009	.894	1.000
1968	.929	1.004	.906	.999
1969	.992	1.010	.912	.998
1970	.933	.980	.900	.989
1971	.894	.972	.919	.990
1972	.949	1.003	1.005	1.001
1973	.958	1.015	.958	1.002
1974	.994	1.011	.905	.999
1975	.821	.939	.804	.972
1976	.869	.971	.883	.990
1977	.895	.990	.914	.997
1978	.853	.988	.865	.996
1979	.823	.976	.791	.988
1980	.749	.924	.741	.964
r_{FED}	.212	.705	.229	.644
r_{WHAR}	.117	.208	.026	.280

The entries in columns 1 and 3 confirm a priori conjectures; the CU_{CV} measures indicate that in general by current-valued criteria, CU is less than unity, implying that considerable excess capacity exists. Note that both these CU_{CV} indices reach minimum values near the beginning and end of the sample period, and drop significantly during slack years such as 1958, 1961, 1975, and 1980, although the 1971 drop in the traditional indices is reflected in 1970 for the general framework. Also, the general expectations measure tends to be slightly more volatile, lower during the first and last part of the sample and higher in the middle, than that based on adaptive expectations. In terms of the "boom" years, the CU_{CV}^{n} measures for the general and adaptive expectations models attain maximal values in 1972 and 1974, respectively, whereas the Wharton and FRB measures peaked in 1973 and 1966, respectively. Other smaller "peaks" in 1955, 1959-60 and 1969 are captured by both the traditional and the economic indices.

By contrast with the CU_{CV}^{n} measures, the entries in columns 2 and 4 for CU_{PV}^{n} are in most cases greater than unity. This is particularly evident in the mid-range of the sample where the general expectations index indicates near-optimal present valued behavior; this implies that almost all observed deviations from capacity can be attributed to anticipatory behavior. Significantly, however, departures from unity are largest in the recessionary years of 1958, 1975, and 1980. The adaptive expectations index in this case is more volatile; it indicates larger variations from the optimum, including a relatively substantial shortfall in economic capacity in present value terms in the mid 1960's and early 1970's. The adaptive expectations framework may provide preferable estimates here, for it can better distinguish between deviations in CU due to earlier errors given quasi-fixed inputs and those due to nonstatic expectations formation. Specifically, since the expectations parameters in the general expectations formation are composite parameters, they may capture all deviations, allowing little role for other "disequilibrium" factors. Relative variations such as drops in 1958, 1970-71 and 1975, and "highs" in 1955 and 1973 are, however, still evident in both measures.

The prevalence of values that exceed unity in these indices suggest that evidence of chronic excess capacity is largely due to the neglect of anticipatory behavior. Since the CU_{PV} measures purge the current investment induced by nonstatic expectations, they more closely correspond to CU measures based on current exogenous variables, and thus to those measures based on the assumption of static expectations (see columns 2 and 4 of Table 2, and columns 3 and 4 of Table 1). The nonstatic expectations framework appears, however, to capture periods of excess capacity more effectively even with the present valued measure; the CU_{PV} measures more often fall short of unity than do the CU_{CV}^{n} and CU_{CV}^{g} indices in Table 1.

Overall, the results are consistent with the notion that in earlier years in the sample when CU_{PV}^{n} was less than unity there was great optimism, which in retrospect was unwarranted; evidence of excess available capacity appears even in present value terms. In the 1960's, demand was sufficiently strong to utilize most of the excess capacity, and in fact created a shortage of capacity during 1963-67 when investment responded less quickly than it should have. By the late 1970's the pattern returned to that observed in the 1950's; substantial excess capacity existed due to unwarranted optimism.

Finally, it is of interest to compare the economic CU measure with the traditional mechanical FRB and Wharton CU indices. As seen at the bottom of Tables 1 and 2, the simple correlation between the CU measures suggest that the economic CU indices, except CU_{CV}^{n} for the static expectations model, better approximate the FRB measure than Wharton. Simple correlations of the CU^n_{CV} measures for the adaptive and general expectations model with the FRB, for example, are .212 and .229, respectively, in contrast to .117 and .026 for Wharton. The .456 correlation between the static expectations CU^g_{CV} measure and FRB, however, is the largest for any static expectations model, whereas for Wharton the corresponding correlation is .195. This implies that the gross shadow value measure better approximates the FRB measure than does the net measure. Another surprising but interesting tendency is for the CU^n_{PV} measures to more closely approximate the traditional measures -- even though they exceed unity -- than CU^n_{CV} with nonstatic expectations incorporated. The CU^n_{PV} measures for the general and adaptive expectations measures have correlations of .644 and .705, respectively, with the FRB measure; these correlations are substantially higher than that between the two traditional measures. The tendency for the CU^g measures to have higher correlations with FRB than the CU^n measure holds also for the nonstatic expectations models. Together these patterns suggest that the current mechanical CU measures are best envisaged as corresponding to no anticipatory behavior and no adjustment costs.

Concluding Remarks

The purpose of this study has been to emphasize the importance of economic foundations for the construction of cyclical economic indicators. More specifically, the derivation of CU measures within an economic framework links capacity utilization measurement to other economic indicators such as the shadow value of capital and multifactor productivity. A common theoretical framework facilitates interpretation and application of the measures.

Specifically, the CU analysis presented here has been based on equating the shadow and market values of capital, and calculating the implied capacity output Y**, which is then compared with the current level of output demand Y. This output "disequilibrium" is closely related to the idea of Tobin's q, an investment indicator based on the deviation between an implicit and market value of capital. The economic CU measures are therefore consistent with theories of investment. In this sense, choice among the various economic CU measures is equivalent to choice among alternative assumptions concerning investment behavior. By contrast, while the mechanical FRB and Wharton measures are often used as regressors in investment equations, their mechanical construction cannot be expected to be logically consistent with theories of investment.

Interpretation of deviations of CU from unity as being due to fixed input constraints also has implications for the purging of cyclical variations from productivity measures. Specifically, use of the mechanical CU measures as an adjustment for short run disequilibrium in productivity measurement has long been questioned because of its lack of theoretical underpinnings. Morrison (1983) has shown that both primal and dual productivity measures can be adjusted by a corresponding economic CU measure to remove the short run effects of quasi-fixity of inputs. This approach has the attractive feature of allowing identification of shifts in production possibility frontiers ("true" productivity changes) from movements along it (the effect of short run constraints on adjustment or "disequilibrium").

In sum, the interpretation of cyclical economic phenomena is enhanced by the formal derivation of economic indicators such as CU within an explicit optimization framework. Moreover, the implications from such an exercise provide a useful basis for further theoretical and empirical work on the analysis of fluctuations in economic activity.

Footnotes

[1] In contrast, with static expectations the firm will not attempt to adjust until the shock takes place at time t, but then must adjust slowly because of costs of adjustment. It is thus optimizing over this time period in terms of current expectations, but not in an overall present value sense as seen from time t_0. For further discussion see Morrison (1982), Essay 2.

[2] This idea was proposed in Berndt and Fuss (1981).

[3] The data on prices and quantities of output, capital, nonproduction and production labor, energy and intermediate material inputs for U.S. manufacturing were graciously provided by Ernst R. Berndt and David O. Wood. For a discussion of these data, see Berndt and Wood (1983).

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