POTENTIAL OUTPUT AND ITS GROWTH RATE - THE DOMINANCE OF HIGHER ENERGY COSTS IN THE 1970'S

Robert H. Rasche and John A. Tatom

Since the early 1960s, the level and the rate of growth of potential output have become increasingly important subjects. While policymaker's and the public's acceptance of these concepts has become widespread, since the early 1970s there has been considerable controversy concerning the measurement of potential output and its growth. By 1973 it had become clear to many observers that the Council of Economic Advisers (CEA) measure of potential output was too high. That measure showed slack in the economy equal to $30 billion (1972 dollars) while many observers thought the economy was operating at or above its potential, at least in the early part of the year.

In mid-1973, Business Week summarized the "Debate Over Gauging the GNP Gap," pointing out the importance of the issue for assessing stabilization policy, particularly for near term inflation and recession prospects. 1/ Lawrence Klein, Alan Greenspan, Geoffrey Moore and others argued that the economy was much closer to full utilization of resources than the CEA potential output measures then revealed. Nevertheless, Arthur Okun and George Perry were said to remain defenders of the slack economy view. Perry is quoted as saying: "I am

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Drs. Rasche and Tatom co-authored this paper while both were employed by the Federal Reserve Bank of St. Louis.

not persuaded that we do not have the industrial capacity to bring the unemployment rate down to 4 percent. To me, the $20 billion gap still looks like a firm number." 2/

Since 1973, energy price developments, the inflation experience, a recession, sluggish capital growth in the recovery, and unusual labor productivity changes have brought the potential debate to a turning point. Within the past year, Business Conditions Digest ceased publication of the CEA series. Peter K. Clark's study, "A New Estimate of Potential GNP," circulated, and the CEA reported a new series for potential output in the 1977 Economic Report of the President. While the revised estimates reduce the previous measures of potential output, the Report points to evidence of the need for further revisions due to a productivity loss since 1974. The Report also suggests that the growth rate of potential is about 3.5 percent -- lower than the prior official view. Early this year a study by Data Resources, Inc., reached a similar conclusion. 3/

In our Review article in May of this year, the theoretical foundations for a loss in economic capacity and potential output due to the 1974 energy price change are derived. Our results support the capacity loss hypothesis which has been discussed in numerous Review articles in the past, an hypothesis which receives indirect support from an investigation of a monetarist price equation. 4/ Our Review article in June provides further empirical support for the loss in economic capacity due to the change in the relative price of energy using a production function approach to measure potential output. The results support the CEA contention that downward revisions are necessary in their revised potential output series for recent years. Nevertheless, our potential output measure appears consistent with the old CEA series until the early seventies, especially in 1955 and 1969-70. 5/

George Perry's, "Potential Output and Productivity," appeared in the July Brookings Papers. 6/ His potential output measures also indicate downward revisions from the old official series, especially for the late 1960s and early seventies when his potential output measures are actually below the new CEA measures. Perry's measure for 1973 shows the economy operating slightly above potential, a point of agreement with Clark. 7/ However, Perry's measure of potential output begins to grow more rapidly in about 1970, and it grows more rapidly than our measure or the new CEA measure of potential output. In fact, Perry's growth rate for 1970-76 is about as fast as that of the old CEA measure which he has repudiated for the earlier period.

The three studies share a general conclusion that, at least through 1973, the old CEA series overstated the potential output of the U.S. economy. There is some difference in the pattern of the downward revisions in each case. Interestingly, both Clark and Perry reduce 1973 potential output by over $30 billion while our measure is only $15 billion below that in the old CEA series. After 1973, there are more serious differences. Our measure shows a substantial effect of energy developments, the others do not. Also, Perry's measures indicate a sharp acceleration in the rate of potential output growth in the 1970s with potential growing much faster than the new CEA estimate.

In this paper we review briefly the theoretical and empirical basis of our earlier potential output results. To provide a context for this review, the discussion focuses upon quarterly potential output measures instead of the annual measures presented in the June article. Our measures of potential output in the June Review and below rely heavily upon Clark's work on the labor force and participation rates. Ignoring energy developments or errors due to assumptions concerning capital growth or growth of non-private business sector output and employment, the growth rate of potential output from our production function analysis should be about equal to his. The only remaining difference would be that our estimated labor, capital, and trend coefficients deviate very slightly from his assumed labor coefficient of two-thirds, and estimated trend term of about 1.55 percent. Thus, in our earlier work we found it convenient to follow Clark's analysis and assume a 3.5 percent rate of growth of potential output after 1976. Since there is a large gap between the CEA and Perry estimates of the outlook for potential output growth, we examine the growth issue as well.

During the recovery (since I/1975), investment in plant and equipment has been a continuing concern to economic analysts, not only because it reflects the business outlook of investors and affects current employment, but also because it affects the future growth of actual output (or, implicitly, the growth rate of potential output). Our research offers an explanation of both the sluggish growth of investment and slower than expected growth in potential output since the recession. Finally, we offer some comments on the prospects for potential output growth for the remainder of the decade.

Quarterly Potential Output: 1949-1977

Until recently, the conventional method for measuring potential output focused upon the relationship between output and labor force growth. The growth rate of potential output depended upon the growth rate of the labor force, secular changes in hours per worker, and labor productivity trends. In several papers, dating back to the original potential output studies, the importance of accounting explicitly for growth in the capital stock is emphasized. The use of an aggregate production function relating potential resource employment to potential output is the obvious solution and one which has been followed most recently by Clark and Brinner. However, they simply employ conventional assumptions: a labor share of income of two-thirds and a residual or capital share of one-third.

Our theoretical work on capacity output suggests that energy price changes have an effect on productivity of domestic labor and capital resources. Moreover, we are not content to fix factor share coefficients, especially since data on energy use is not collected in a form which allows ready computation of its factor share in cost. Thus, our work begins with a production function, but the coefficients of the three resources - labor, capital, and energy - are estimated. From this production function, potential output is measurable given assumptions concerning potential resource employment.

A Quarterly Aggregate Production Function

The fundamental relationship used for measuring potential output is a production function for private business sector output. Output

(Y) is hypothesized to be a function of hours of all persons (L), capital (K), energy (E), and disembodied technological progress. The production function is Cobb-Douglas and r is the constant trend rate of growth.

(1) $$Y = Ae^{rt}L^{\alpha} K^{\beta} E^{\gamma}$$

The demand for energy may be derived from the production function and the rate of energy usage found by equating the supply of energy to the demand for energy, assuming the economy is a price taker in the energy market. Substituting the equilibrium quantity of energy in the production function yields

(2) $$Y = (A^{*} e^{rt} L^{\alpha} K^{\beta} P^{-\gamma})^{1/1-\gamma}$$

where P is the relative price of energy, measured by deflating the wholesale price index for fuel, related products, and power by the implicit price deflator for private business sector output. 8/ Hours of all persons data and output for the private business sector are prepared by the Bureau of Labor Statistics of the U.S. Department of Labor.

The capital stock data is based upon interpolation of the end-of-year net stock of fixed nonresidential equipment and structures prepared by the U.S. Department of Commerce. 9/ The interpolation uses quarterly rates of constant dollar nonresidential fixed investment in the GNP accounts as weights in finding end-of-quarter net capital stocks. The flow of capital services is computed by multiplying the previous end-of-quarter capital stock by its utilization rate as measured by the Federal Reserve Board index of capacity utilization.

Since a consistent measure of the end-of-year capital stock is only available with a lag, estimates of the quarterly capital stock after 1975 had to be found from the prior (II/1948IV/1975) relationship of quarterly changes in the net stock to the quarterly rate of nonresidential fixed investment and, to account for depreciation, the lagged net capital stock. The equation is:

(3) $$K_t - K_{t-1} = \underset{(4.5)}{1.012} + \underset{(29.2)}{.2457}\, I_t - \underset{(-21.4)}{.0252}\, K_{t-1}$$

$R^2 = .98$ D.W. $= 2.10$

S.E. $= .37$ $\hat{\rho} = .49$

where K_t is the constant dollar net stock of equipment and structures at the end of quarter t and I_t is constant dollar nonresidential fixed investment in quarter t.

The quarterly production function, estimated for the period II/1948 - IV/1975 with a linear homogeneity constraint, is:

(4) $$\ln Y = \underset{(13.77)}{1.5380} + \underset{(21.24)}{.7226} \ln L + \underset{(8.15)}{.2774} \ln K$$

$$- \underset{(-5.05)}{.1040} \ln P + \underset{(15.35)}{.0046}\, t$$

$R^2 = .98$ D.W. $= 1.93$

S.E. $= .0076$ $\hat{\rho} = .80$

The indirect estimates of the production function parameters are (standard errors in parentheses)

$\hat{\alpha} = 65.5\%$ (3.09%), $\hat{\beta} = 25.1\%$ (3.09%), $\hat{\gamma} = 9.4\%$ (1.86%),

$\hat{r} = .4\%$ (.03%)

The estimated equation and the output elasticities are not significantly different from the annual estimates or the quarterly estimates reported in the June article. [10/] As earlier, the estimated elasticity of energy is lower than that found using annual data. Therefore, the energy price effect will appear smaller in the potential output series. The quarterly production function above was also estimated with the output elasticity of energy constrained to be 12 percent, the estimate found using annual data. An F test of the constraint indicated that ($\hat{\gamma}$ = 12%) could not be rejected ($F_{1,106}$ = .66).[11/] Nontheless, the more conservative estimate of γ is used below.

Some statistical properties which we reported in the June article bear repeating. First, the production function is stable when estimated through 1973 or 1975. When energy is omitted from the production function, adding the observations for 1974-75 results in a sharp decline in the estimate of the output elasticity of labor and a significant rise in the standard error of the equation. A Chow test on the additional observations indicates structural change when energy is omitted from the equation, but not when it is included. Second, in our discussion (Appendix II) of potential biases in the estimation due to the assumed Cobb-Douglas production function, we noted that if the own-price elasticity of demand for energy is not unity, our assumption imparts a downward bias to the estimate of the output elasticity of energy (γ) and an upward bias to the output elasticity of labor (α). The consistency of the estimate of α with the labor share data indicates that this bias, if present, is not substantial. In any event, even if this bias were present, it would not bias the estimated regression coefficients upon which the potential output measures are based.

In estimating the annual production function for the June article we attempted to account for other factors which have been cited as influencing productivity in the last decade and which are believed by many to have lowered potential output in recent years. Such adjustments involve the labor force, capital and trend measures. An attempt to adjust for the quality of hours in the production function by accounting for the labor force share of young people proved to be statistically insignificant. An adjustment to the gross capital stock to remove pollution abatement capital does not affect the coefficients or improve the standard error of the production function and does not appreciably affect the measure of potential output either. A break in the trend rate of growth was also allowed because of an observed slowdown in productivity growth since 1967. The slowing of the trend was statistically significant, but, lacking a explanation for it, we have chosen to ignore it.

It may appear that the break in the trend has important implications for the prospective growth rate of potential output. Instead, the major effect is to raise potential output measures in the mid-1960s. Trend terms with a break in 1967 show trend growth to be at a 2.02 percent rate prior to 1967 and 1.55 percent since then. The trend growth in the production function above of 1.6 percent is not markedly greater than the current trend rate where a trend growth slowdown is allowed.

Hours Per Worker

Potential hours per worker in the private business sector in the June paper is found from an equation relating hours per worker to a trend and a cyclical variable -- the unemployment rate of the civilian labor force -- estimated for the period from the second quarter of 1948 through 1975. Two changes have been made to measure potential hours per worker. First, for consistency the cyclical variable has been changed to the difference between the actual unemployment rate and the full-employment unemployment rate. This change has little effect on the regression equation. 12/

The second change is to allow for the unusual behavior of hours per worker in the 1961-67 period by using a dummy variable. Inspection of the earlier results reveals that the equation has systematically large errors (more than one standard deviation) for every quarter from mid-1961 through the first quarter of 1967. More importantly, the actual hours per worker exceed the estimated potential levels throughout the period by relatively large amounts. Various specifications were tested, including alternative time intervals for a temporary or permanent shift and changes in the trend rate of decline of hours per worker. The time interval chosen and a temporary (versus permanent) shift upward in hours per worker fit the observed error pattern most closely and yielded the lowest standard error. Tests for a break in the trend rate of decline in hours per worker failed to support such an hypothesis once the temporary shift upward was taken into account. Also a comparison of equations allowing only a break in the trend or only the temporary shift in the level of hours per worker revealed the temporary shift yielded the lowest standard error. 13/

The equation for hours per worker is:

$$\ln HPW = .7983 - .3229\ UN - .0010\ t + .0136\ D$$
$$(1004.6)\quad(-10.7)\qquad(-36.1)\qquad(13.1)$$

$R^2 = .99$ D.W. = .74

S.E. = .004 Sample: II/1948-IV/1975

where HPW is hours per worker, UN is the excess of the unemployment rate over its full-employment rate, t is time, and D is a dummy variable which rises to one in steps of one-fourth beginning in the third quarter of 1961, and phases out in the same way reaching zero in the second quarter of 1967. 14/

Potential hours per worker are found by setting UN equal to zero. It should be noted that potential hours per worker in the mid-1960s are higher than our previous estimates so that the difference between our measure of potential output and the old CEA measures appear smaller than in Chart IV of the June paper.

Quarterly Potential Output

To measure potential output, potential resource employment in the private business sector and the potential output in the remainder of the economy must be measured. Actual output is assumed to be potential output for sectors of the economy which are not included in the private business sector (general government, rest of world, imputed output of housing, and output of households and nonprofit institutions). Capital employment is assumed to be the services of the capital stock at an 87.5 percent FRB capital utilization rate. This utilization rate was chosen as a full-employment measure because it was the prevailing rate during the benchmark year of 1955 and in other peacetime full-employment periods. Energy employment is assumed to be that demanded at potential output, given the actual relative price of energy in each quarter.

Potential hours of all persons are measured by combining measures of potential private business sector employment and potential hours per worker. Potential private business sector employment is found by subtracting the number of unemployed at full-employment from Clark's measure of the potential civilian labor force to obtain potential civilian employment and then subtracting actual employment outside the private business sector. 15/

The assumptions upon which the potential output measures are based are, if anything, very optimistic and may result in overestimates of potential output, especially in recent years. First, by using the estimate of the output elasticity of energy employment of 9.4 percent instead of the 12 percent estimate from the annual regressions, the impact of energy price increases is lowered. Second, Clark's series for the full-employment unemployment rate may lead to a significant overstatement of potential employment. Wachter (BPEA, 1:1976 and BPEA, 1:1977, pp. 4851) has made a strong case for the full-employment unemployment rate being higher in recent years than the Clark and Perry estimate. (His work also implies a slower rate of growth of the potential labor force). Similar measures have been derived in a recent paper by Ronald Talley. 16/ Finally, the measures may be overly optimistic because they do not adjust for the factors discussed earlier which would all tend to reduce potential output in recent years such as pollution abatement investment, the changing composition of the labor force and slowdown in the trend growth of factor productivity.

Measures of quarterly potential output from II/1948 through II/1977 are presented in Table 1. These measures are compared to others for selected years in Table 2 where annual averages of quarterly measures are shown for selected years. The other measures are those of the CEA until January 1977, called "old CEA," the CEA measures reported in January 1977, called "new CEA," and Perry's second series which does not have a break in trend growth. Using the old CEA series as a standard, it may be seen that our measure is fairly close in 1955 and 1970 (closer than either the new CEA measure or Perry II). Comparison to measures in 1960 and 1965 indicates that our estimate of the growth rate of potential in the late 1960s is higher than the others while our estimate of potential growth is slower than the others during the earlier period, especially from 1955-60. From 1970 until 1973, our measure is below that in the old CEA series, but it is closer than the other two measures. By 1973, both the CEA and Perry reduce the old CEA measure by sizable amounts ($37 and $32 billion, respectively). In contrast, our measure is only about $16 billion below the old CEA measure. Figure 1 shows the differences between three of the measures from 1972-80 and actual output through mid-1977.

After 1973, our measure shows the impact of the loss of potential output due to the large increase in the relative price of energy. By 1976, our measure is over $80 billion below the old CEA

TABLE 1

QUARTERLY POTENTIAL GNP
(Billions of 1972 Dollars at Annual Rates)

	I	II	III	IV
1948		486.1	500.4	501.8
49	513.1	520.7	526.1	526.8
50	533.0	537.7	543.6	552.2
51	562.9	572.4	578.9	584.0
52	592.1	593.2	601.9	611.2
53	615.2	616.4	618.0	621.2
54	629.2	632.6	639.3	641.5
55	646.7	651.6	661.8	669.7
56	669.7	676.8	680.5	683.9
57	686.8	692.3	702.9	704.8
58	708.3	720.5	730.7	732.9
59	731.4	740.1	743.7	754.2
60	757.6	764.0	767.1	775.2
61	783.6	789.0	798.1	803.2
62	810.6	819.5	824.0	822.3
63	829.9	835.9	848.5	856.7
64	866.2	873.8	879.3	880.5
65	890.6	902.9	912.7	921.6
66	935.0	950.0	959.3	967.7
67	978.0	982.2	996.1	1006.9
68	1012.4	1027.0	1035.2	1045.3
69	1056.9	1071.3	1084.8	1092.4
70	1100.9	1111.9	1121.3	1125.3
71	1137.4	1151.0	1155.7	1167.0
72	1178.0	1194.8	1209.4	1222.5
73	1231.6	1244.4	1257.0	1265.4
74	1259.6	1259.0	1265.9	1279.7
75	1283.0	1294.1	1307.7	1315.9
76	1324.8	1335.9	1347.9	1353.8
77	1361.0	1366.9		

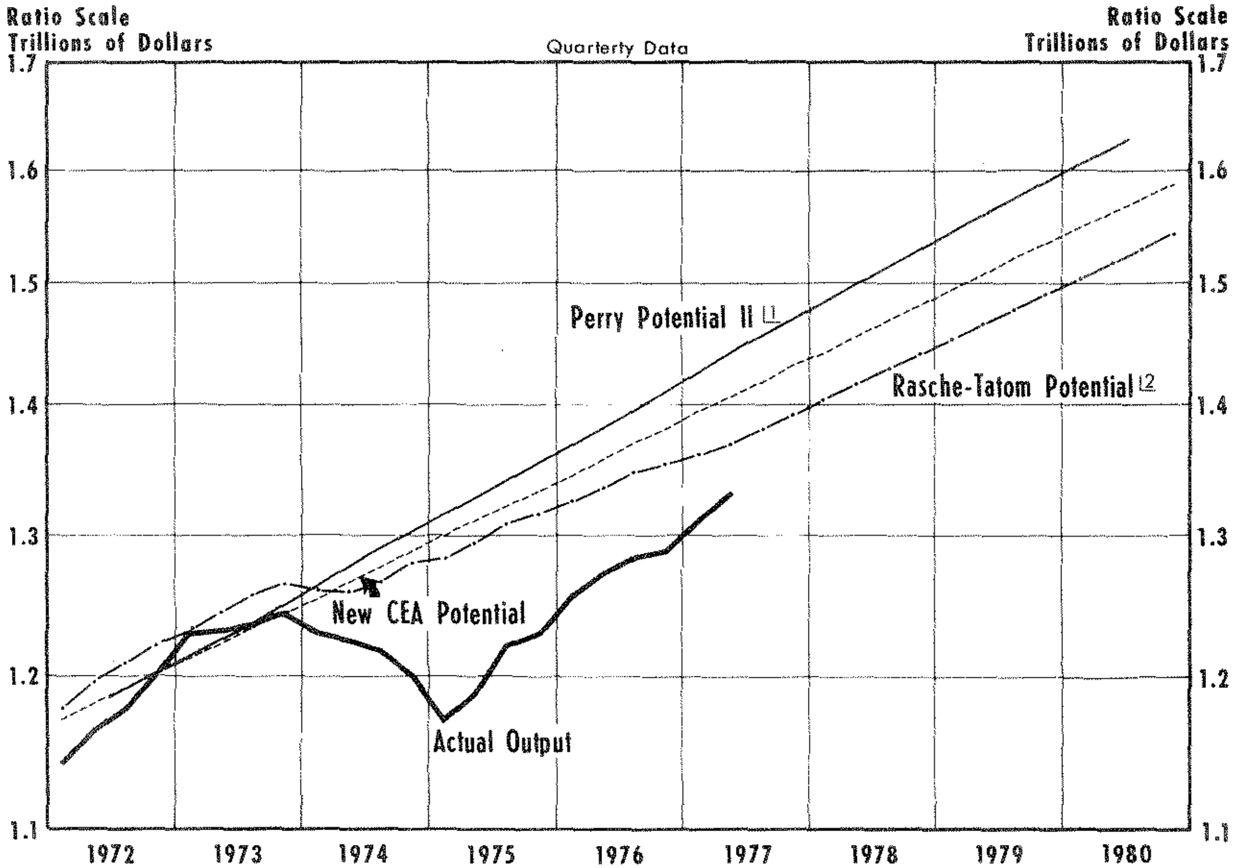
TABLE 2

Alternative Measures of Potential Output
(Billions of 1972 Dollars)

	Rasche-Tatom	Old CEA	New CEA	Perry II
1955	657.5	656.6	651.4	657.8
1960	766.0	779.9	771.9	775.1
1965	907.0	932.1	925.0	918.0
1970	1114.9	1124.4	1106.2	1091.7
1971	1152.8	1169.9	1145.5	1136.0
1972	1201.3	1216.7	1186.1	1184.8
1973	1249.7	1265.4	1228.2	1233.1
1974	1266.1	1315.9	1271.7	1283.6
1975	1300.2	1368.6	1316.9	1334.9
1976	1340.5	1421.2	1363.6	1388.1

FIGURE 1

Actual Output and Alternative Potential Output Measures



Sources: U.S. Department of Commerce, Council of Economic Advisers, and George Perry, Brookings Papers on Economic Activity (I:1977).

[1] George Perry's series is an annual measure.

[2] Potential output grows at 3.5% after 2nd quarter 1977.

Latest data plotted for Actual Output: 2nd Quarter 1977

Prepared by Federal Reserve Bank of St. Louis measure, $48 billion below Perry's measure and $23 billion below the new CEA measure. Comparing real GNP to potential output yields markedly different measures of the GNP gap in 1976. The new CEA gap of 6.5 percent, Perry's gap of 8.2 percent and the old CEA gap of 10.3 percent of potential output imply that economic performance was worse during 1976 than in any previous postwar year except 1975. In contrast, our measure of the gap is below all postwar recession years except 1970-71.

Thus, Heller's recent claims that the difference between alternative measures of potential output is small and that there is considerable slack in the economy seriously misstate the case. 17/ He apparently converts the revised CEA measure of 1412.0 and Perry's Potential I measure of 1436.7 for 1977 to current dollars and concludes that in current dollars the gap is $116 billion to $148 billion. The highest potential measure, the old CEA estimate would, if allowed to grow at 3.75 percent -- its 1976 rate -- imply a gap of $200 billion. Perry's Potential II estimate yields a gap of $165 billion. At the other extreme, the new CEA measure -- adjusted using their conservative measure of the productivity decline due to energy developments -- would imply a current dollar gap of about $69 billion. Our second quarter potential measure, on the same basis, implies an even smaller gap of about $57 billion. One may question whether the $200 billion measure should be taken seriously since the CEA apparently does not. However, a recent study for the Joint Economic Committee suggests the gap is even larger than the old CEA measure implies. 18/ Nonetheless, a range of $57 to $200 or even $165 billion in alternative measures of the current dollar GNP gap does not seem very close and the difference in gaps of 3 percent of potential output versus 10 percent is staggering in itself as well as for what it might suggest to activist policy-makers.

Table 2 also indicates that in recent years our measure of potential output has been growing more slowly. This must be the case when 1974 is in the interval over which the growth rate is computed since our measure includes the potential output loss due to the energy price change while others do not. But, even for 1975 to 1976 our growth rate of 3 percent is markedly below the new CEA's 3.5 percent, the old CEA's 3.75 percent or Perry's 3.9 percent.

While an assessment of the size of the GNP gap is important for understanding the recent performance of the economy, a measure of the prospective growth rate of potential output, while more difficult to pin down, is equally important for policy-making purposes.

The Growth Rate of Potential Output: 1975 - 80

The growth rate of potential output from 1975 to 1977 has been below both the CEA and Perry estimates. It is easy to understand why this is the case for Perry's estimate since it follows so closely the old method of estimating potential growth which concentrated on potential growth in labor employment and trends in labor productivity. As Otto Eckstein has noted, this method may have yielded plausible results in the past, but too many studies show that its results are implausible in the seventies because it does not examine the changing factors determining labor productivity. [19/]

The rise in energy costs can explain the slow growth of potential output over the last two years. While the increase in the relative price of energy has been less dramatic over the last two years, from the fourth quarter of 1974 through the first quarter of this year the relative price has increased 10 percent. Our earlier work, it will be recalled, concerned the effect of a 35 percent increase in the prior year. The energy and energy price coefficient estimates in the production function above indicate that, spread over two years, a 10 percent increase in the relative price of energy reduces the growth rate of private business sector potential output by half a percent: the difference between Clark's estimate of potential output growth (3.5%) and our measure of the growth of potential (3.0%).

Moreover, economic theory suggests a short-term effect on the future growth rate of potential output due to the large 1974 increase in the relative price of energy. In particular, a rise in the relative price of energy depresses the demand for existing supplies of capital resources and, if new capital is energy intensive relative to the remainder of the economy, raises the relative supply price of those goods. Thus, investment falls below what it otherwise would have been for some period until a desired capital output ratio is restored. Such "sluggish" capital growth has been observed over the last two years and has had a retarding effect on the growth rate of potential.

The effect of a higher relative price of energy on the growth of potential resources is more fully discussed in the next section. Then we turn to the outlook for potential output growth in the remainder of the decade. Since this outlook depends on prospective energy price developments, some attention is devoted to this issue as well. Speculation on how fast a non-observable economic variable such as potential GNP will grow should be considered "second order metaphysics", with apologies to practitioners of the subject. Nonetheless, it is useful for understanding the near-term growth, employment and inflation possibilities of the economy and for policy formulation purposes to examine the question.

The Implications of the 1974 Capacity Loss for the Growth Rate of Potential Output

Our analysis of the 1974 rise in the relative price of energy shows that the productivity of existing labor and capital resources fell. The production function estimates bear out the direction and magnitude of the productivity loss. We did not explore the impact of the loss in potential output on the future rate of growth of potential output. However, the analysis which yields the loss in potential output also suggests a decline in the rate of growth of potential for some period in the future. In particular, the supply of plant, equipment and labor resources can be affected due to a rise in the cost of energy. With given supplies of potential capital and labor, the demand for each falls when the relative price of energy rises. These shifts in the demand for resources measured in terms of decreases in their rental prices may lower the growth of labor and capital resources and reduce the future potential output rate.

The conventional analysis of the labor supply decision suggests that there are two major impacts of the energy price increase. The shift in demand for labor services tends to reduce real wages. Such a reduction in real wages induces both a substitution effect and an income effect which tend to reduce the full-employment supply of labor somewhat. [20/] The second impact arises from a change in the value of non-human wealth. The price level impact of the higher relative price of energy reduces the real value of net monetary wealth. At the same time, the lower productivity of existing capital assets reduces the present value of those assets. Given that leisure is a normal good, such a reduction in real wealth tends to increase the full-employment supply of hours of all persons. It is not possible, a priori, to sign the effect of the energy price increase; the wealth and labor income effects tend to increase the labor supply while a substitution effect tends to reduce it. We know of no evidence that there is a net effect on the full-employment supply of labor in either direction. [21/]

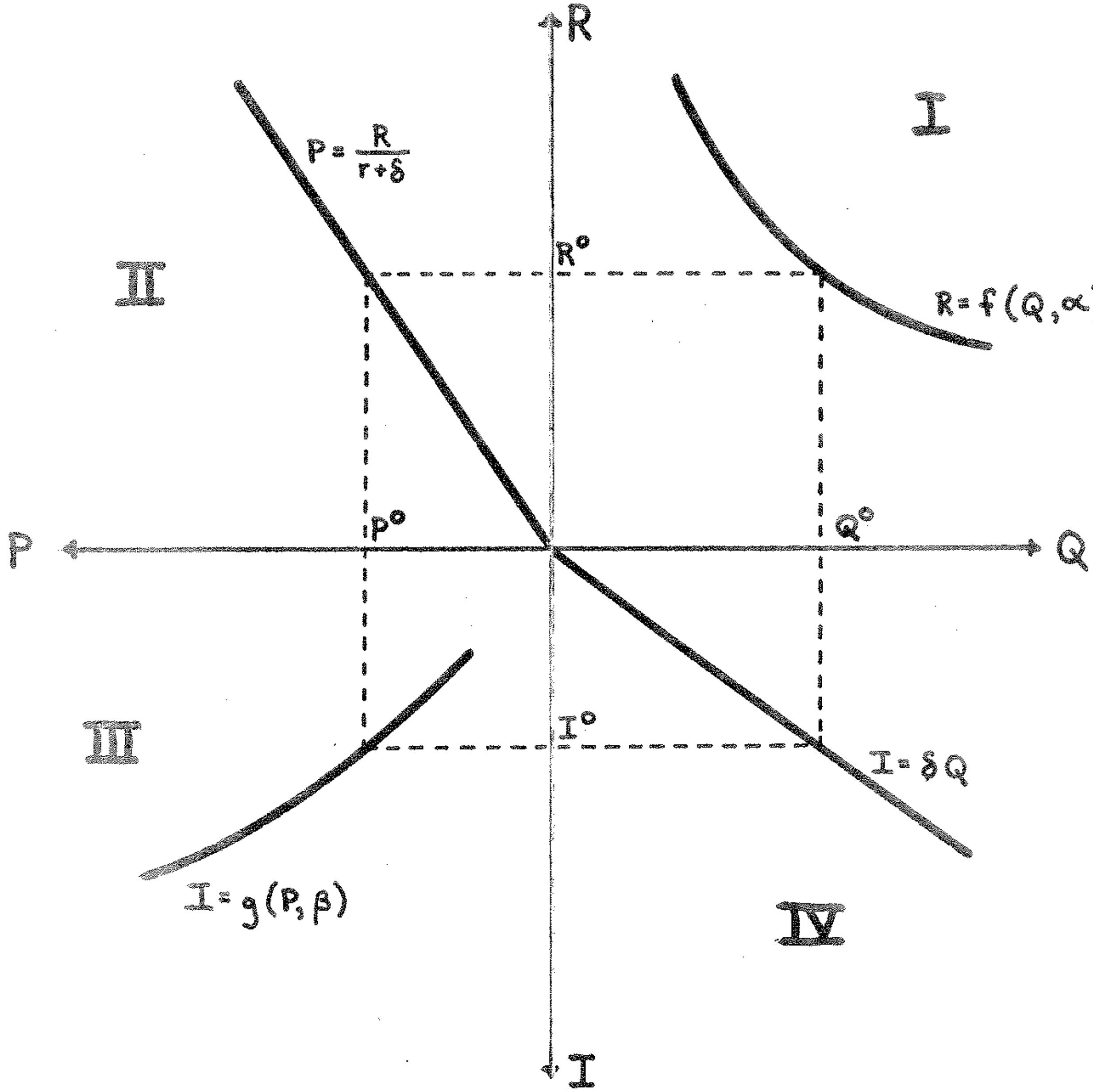
In the case of capital resources, the result is much clearer. The reduction in the rental price of existing capital due to a leftward shift in the demand for the stock or flow of services of capital also shifts the demand for new capital goods. Other things equal, investment tends to fall, as does the steady-state stock of capital. [22/] Other things are, of course, not equal. In particular, the replacement cost of capital, or the supply price of new capital goods, may be expected to change as well. If capital goods are more energy intensive than aggregate output, as one would expect, the relative supply price of capital goods would tend to rise. [23/] Since both the demand and supply of new capital goods tend to fall, investment falls a fortiori as does the long-run equilibrium capital stock.

A simple model relating the rental price of capital, the price of new capital goods, the stock of capital, and the investment rate illustrates these points. [24] Figure 2 illustrates the steady state relationship between the variables. In Quadrant I the flow demand for the services of capital, Q, is shown as a function of its rental price, R, and parameter α. The services of capital are assumed to be proportional to the stock of capital, K. In Quadrant II, the price of a unit of the stock of capital is related to the rental price as a discounted perpetual gross income stream where r is the real rate of interest and w is the depreciation rate. Quadrant III shows the supply of new capital goods, I, in terms of the price of a unit of capital and the shift parameter, β. Finally, Quadrant IV shows the steady state relationship between gross investment, I, and the stock of capital, K, which is proportional to Q. At Q°, I°, P°, and R° and the implied K° the economy is in an initial steady state equilibrium.

An increase in the relative price of energy shifts the demand for the services of capital downward and to the left. Given the existing capital stock K°, and services Q°, the rental price falls as does the demand price of new capital goods. Investment is less than replacement so the capital stock declines. The new steady state solution occurs at a lower rental price, price of new capital, and with a smaller capital stock and flow of capital services.

An increase in the supply price of new capital shifts the supply curve in Quadrant III upward and to the left. The process of returning to the steady state through temporary negative net investment is easily traced through the graph. The result is a higher steady state price of

FIGURE 2



R
I
$P = \frac{R}{r+\delta}$
R^o
II
$R = f(Q, \alpha)$
P
P^o
Q^o
Q
III
I^o
$I = \delta Q$
$I = g(P, \beta)$
IV
I

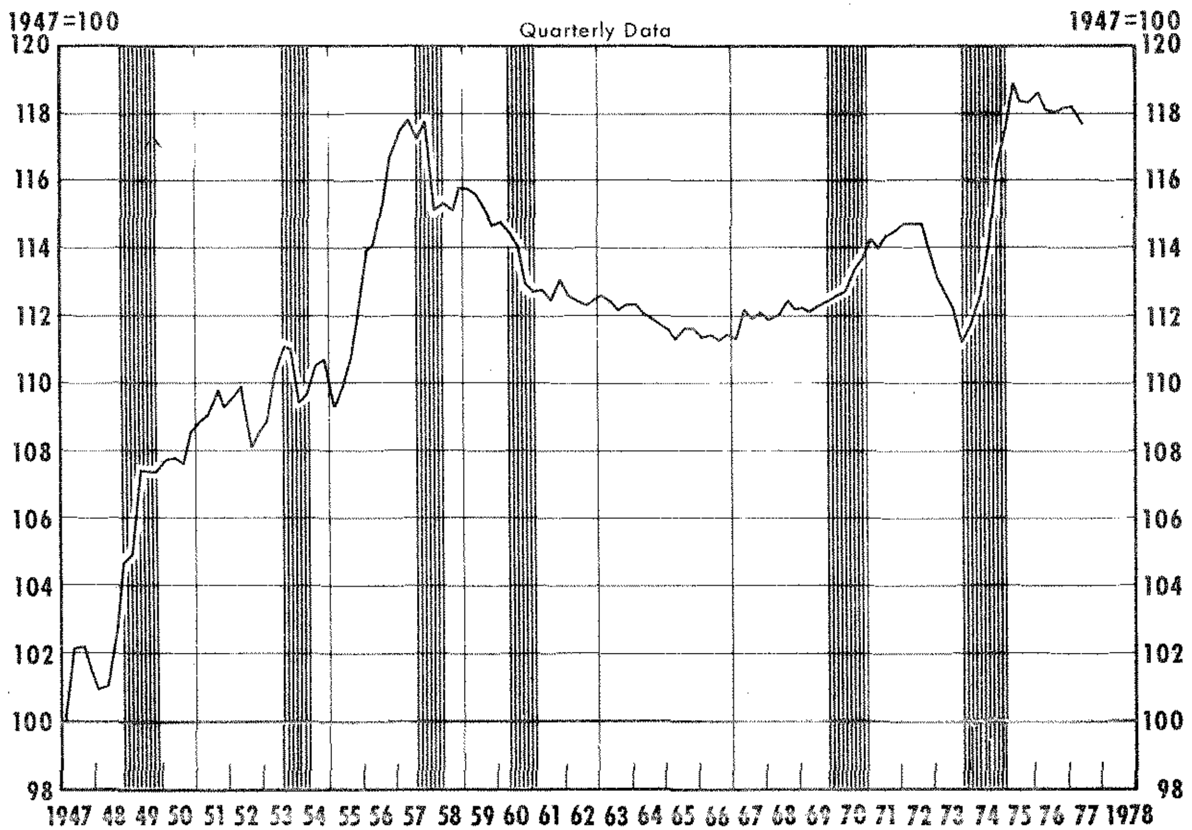
capital, a lower stock and rate of replacement of capital and a higher rental price. Finally, combining both shifts yields a smaller capital stock in the steady state -- achieved through a temporary decline in the net investment rate. Whether the steady state price of capital and rental price of its services is higher depends on the dominance of the initial reduction in the supply of capital goods over the reduction in demand for the services of capital. 25/

Figure 3 shows the GNP price deflator for plant and equipment relative to the PBS deflator. Table 3 shows the slow rate of growth of capital in the last two years compared to the rate of investment since 1949, and to subperiods since then. The rise in this measure of the relative price of capital goods in 1974, as well as recent investment behavior, are consistent with this theoretical analysis and the increased replacement cost hypothesis. 26/

In summary, the sluggish growth of capital in the recent past is consistent with the lower productivity of existing capital resources as well as the increased relative price of capital goods, both of which are consequent to the large increase in the relative price of energy. Such a slowing in capital growth is merely transitional so that, in a growing economy with the absence of further resource supply shocks, growth of capital resources eventually approaches its normal relationship to the growth of labor resources and potential output. The energy price change not only reduces the potential output yielded by a particular rate of use of services of labor and capital, it may also leave the economy with fewer capital services than would have otherwise been the case, after some period of adjustment.

FIGURE 3

Relative Price of Capital Goods*



Sources: U.S. Department of Commerce and U.S. Department of Labor

Shaded areas represent periods of business recessions.

Note: First quarter 1947=100

*Ratio of price index of non-residential fixed investment to price index of output in the private business sector.

Latest data plotted: 2nd quarter

Prepared by Federal Reserve Bank of St. Louis

TABLE 3

The Rate of Growth of Plant and Equipment
(Constant Dollar Net Capital Stock)

Period	(Growth Rate)
I/1950 - I/1955	4.2%
I/1955 - I/1960	3.6
I/1960 - I/1965	3.3
I/1965 - I/1970	5.5
I/1970 - I/1975	3.7
I/1975 - I/1977	1.8
I/1950 - I/1977	3.9

The Prospects for the Relative Cost of Energy

Energy prices have been heavily influenced by Federal regulations since the price control program announced in August, 1971. This has been especially true for petroleum markets since 1973 when OPEC actions raised the world price of crude oil above the protected market price in the United States. In order to insulate the U.S. economy from the very large increases in the world price of oil, regulations were put in place to prevent domestic crude oil owners from receiving "windfall profits" and to avoid the recessionary impact of increased petroleum prices. 27/

The centerpiece of existing regulation is the crude oil entitlements program, a method for allocating controlled domestic crude oil among competing refiners. The essence of the program is to provide an "equal" claim on controlled oil to all refiners based on their total oil inputs. The effect of the program is to equalize the price of crude oil to all refiners at a level which is a weighted average of the controlled price and the world price, set by OPEC, where the weights are based on the share of imports and domestic oil in total oil inputs. Thus, the entitlement program provides a means for holding the domestic price of energy below the world price and a means for distributing the "rents" which would otherwise accrue to domestic crude producers.

Existing regulation has worked to hold the price of crude oil to domestic buyers below the world price, but to allow it to gradually rise toward the world price. In the process, of course, imports are implicitly subsidized with the rents expropriated from domestic crude oil owners. Not only are refined products cheaper than they would be

TABLE 4

The Composite and Imported Refiner Acquisition Cost of Crude Oil

		Import Cost (Dollars/Barrel)	Composite Cost (Dollar/Barrel)	Percent Difference
1974	I	11.59	8.24	34.1%
	II	12.93	9.34	32.5
	III	12.65	9.20	31.8
	IV	12.60	9.30	30.4
1975	I	13.03	9.83	28.2
	II	13.56	9.98	30.7
	III	14.11	10.72	27.5
	IV	14.84	10.96	30.3
1976	I	13.35	10.58	23.3
	II	13.43	10.72	22.5
	III	13.52	10.94	21.2
	IV	13.59	11.26	18.8

Source: Based on data from the National Energy Information Center Monthly Energy Review (April, 1977), p. 73.

in the absence of the regulations because of the incentive to produce more, but competing energy sources tend to have lower prices as well, due to their smaller demand.

Table 4 shows the "Refiner Acquisition Cost" of imported oil and the composite cost which is the weighted average of the price of domestic and imported oil from 1974 through 1976. These costs are, in effect, delivered prices, but they reflect the impact of the control program. The last column shows the percentage by which the world price, measured by the refiner acquisition cost of imports, exceeds the composite, or domestic price. Over time, this excess has fallen due to both the actions of the Federal Energy Administration (FEA) in its attempt to gradually remove the difference, and due to the increasing share of high cost imports in total crude usage and the falling share and rate of production of "cheap" domestic crude oil due to the domestic price controls.

Existing regulations and major proposals for a new energy policy envision the "rationalization" of the domestic petroleum market so that domestic prices and energy usage are based upon social costs or reflect economic scarcity (even if artificially imposed). This is evident, for example, in the Energy Conservation and Production Act of 1975 (ECPA) which allows controlled domestic prices to rise over time and terminates domestic price control in 1979. The crude oil tax of the Administration's energy policy proposal as well as crude oil decontrol proposals share this desired result. Thus, it is very likely that the disparity in petroleum prices, shown in Table IV, of about 20 percent at the end of 1976 will be eliminated before the end of 1980.

A 20 percent rise in the cost of crude oil to domestic refiners will not only raise the price of refined products, but also, through substitution effects on energy users and direct and indirect cost effects an competing energy producers, raise the price of other energy resources. To assess the impact of raising domestic crude oil costs to the world price on the relative price of energy resources and on potential output, we have examined the relationship between the relative price of crude oil and of energy prior to the deluge of controls on primary, intermediate, and retail markets which began in August, 1971.

The relative price of energy is that used in our aggregate production analysis and the wholesale price of crude oil is used as a measure of the domestic cost of crude oil prior to August, 1971. The relative cost of crude oil is found by deflating by the implicit price deflator for the private business sector. The simple linear regression of first differences in the logs of the relative price of energy (P) on the relative price of domestic crude oil (P_c) from II/1948 through II/1971 is:

(6) $$\Delta \ln P = - .0021 + .4354 \, \Delta \ln P_c$$
$$(-1.68) \quad (5.18)$$

$R^2 = .23$ D.W. = 1.77

S.E. = .010

This simple regression may be used to obtain information on the increase in the relative price of energy resources occasioned by the expected rise in domestic crude prices and the average cost of crude oil to domestic consumers. 28/ Given the 18.8 percent disparity in prices at the end of 1976, the equation indicates an 8.2 percent rise in the relative price of energy as the disparity is removed sometime over the next three years.

The 8.2 percent rise in the relative price of energy in the United States assumes no change in the relative price of energy or crude oil in the world market. To the extent that our imports of energy resources would be reduced, there is some possibility that the wealth maximizing price of the "dominant firm", the OPEC producers, might change. The fundamental question is the effect of such a U.S. policy change on the elasticity of world demand for OPEC oil. A simple reduction in demand is not likely to lower the relative price of OPEC oil. The relative price of oil and other energy resources would tend to decline in the world market only if demand became more elastic and this would not necessarily occur simply because of a reduction in U.S. imports. An increased responsiveness of domestic supplies to the world price would tend to reduce the elasticity of demand for OPEC oil and other energy imports and, thus, tend to reduce the cartelized world price of oil. However, only decontrol of domestic energy markets would ensure such responsiveness of domestic suppliers and such a policy does not appear likely over the next three years. Taxing existing supplies to raise their cost to the world level implies little or no responsiveness of domestic supplies to world prices and, to the extent such a policy change actually reduces that responsiveness, provides a case for an even higher domestic and world price of energy resources. Thus, an 8.2 percent rise in the relative price of energy resources sometime over the next three years appears to be a reasonable prospect.

The Future Growth Rate of Potential Output

In order to find the growth rate of potential output, assumptions concerning the growth of potential resources are necessary. We briefly describe the assumptions which we use below. In each case we have tried to choose the most optimistic among alternative assumptions.

The Non-Private-Business Sector and Employment Growth -- While output outside the private business sector (PBS) has grown with time, it is not significantly affected by employment. A quarterly regression of non-PBS output on employment, the unemployment rate of the civilian labor force, and time for the period II/1948 - II/1977 indicates that only the time trend of 3.24 percent per year is significant (t=12.2). The t-statistics of the insignificant variables are less than .25. The equation is adjusted for autoregression and has an R^2 of .997 and standard error of 1.6 percent. The growth rate of non-PBS output during the past two years has also been 3.24 percent, while it was lower (2.7%) in the prior five years (II/1970 - I/1975). Thus, it appears reasonable or perhaps slightly optimistic to assume the trend rate will continue.

Employment growth in the non-PBS sector is important because it limits the growth of PBS potential employment and output. Employment growth in the private business sector contributes more to total output than an equivalent increase in employment in the non-PBS sector. In the post-war period, non-PBS employment has grown more rapidly than potential or actual PBS employment. Nonetheless, to maintain an optimistic bias in the growth rate of potential output, it is assumed that the future growth rate of potential employment in the private business sector is the same as the growth rate of potential employment.[29/] Potential employment growth is found using Clark's estimates of the potential civilian labor force and full-employment unemployment rate. The rate of growth of potential employment is 1.65 percent per year while hours growth is 1.25 percent per year in the private business sector from II/1977 through 1980.

<u>The Growth Rate of the Net Stock of Plant and Equipment</u> -- The most difficult problem in assessing future potential output growth is finding the growth rate of the capital stock. As Table 3 indicates, the growth of capital has been relatively slow in recent years, but over a few five year intervals in the past, has been at relatively rapid rates. Since it is difficult to determine whether the transitional adjustment of the capital stock to a higher relative price of energy is complete, and also since future increases are likely which may not have been anticipated by investors, a continued low rate of investment should be allowed for as a possible outcome. To do this, we include a low estimate of potential output growth based on capital growth of 1.8 percent per year, the rate of increase of the past two years.

A more optimistic measure of capital growth may be found from the relationship of capital growth to potential output growth before 1973. The mean rate of growth (annual rate) of capital exceeds that of potential output for the period II/1948 - IV/1973 by .55 percent. This relationship may be used to estimate a rate of capital growth .55 percent faster than the growth rate of potential output.

Energy and Trend Growth -- Trend growth is allowed to remain at 1.6 percent per year in the private business sector. The impact of energy developments may be seen more clearly by measuring the growth rate of potential output assuming no change in the relative price of energy between now and the end of 1980. Combining the assumptions above concerning potential resource employment with the production function (4) yields an annual rate of growth of potential output of 3.8 percent. If investment continues to yield the low rates of increase in plant and equipment of the last two years, the growth rate of potential would be reduced to 3.2 percent. The higher rate is predicated upon a much larger rate of growth of the capital stock (4.4 percent per year). Only one of the five year intervals shown in Table 3 shows growth of the capital stock of 4.4 percent per year or above, the period 1965 to 1970. However, capital stock growth has attained this rate during other periods of peak performance, such as the mid-1950s and during 1973.

The potential output growth rates of 3.2 - 3.8 percent assume no change in the relative price of energy. Accounting for an increase in the relative price of energy of 8.2 percent some time over the next three years noticeably reduces the rate of growth from the present to the end of 1980. The additional energy price change will very likely tend to be a temporary shock with much of its effect occurring over a short period of time. Nonetheless, since the timing of the change is currently unknown, the best that can be done is to show its impact on the growth rate over the longer period. Such an increase in the relative price of energy reduces the maximum expected growth rate of

3.8 percent to 3.5 percent. The implicit rate of growth of the capital stock to achieve this result is 4.1 percent, essentially the mean annual rate of growth of capital from II/1948 through 1973. If capital grows at the rate of the last two years, 1.8 percent, the rate of growth of potential output will be only 3.0 percent per year, the rate achieved so far since 1974.

The results frame the alternatives quite well. Perry's estimated growth rate of potential output for the next few years is roughly equal to our highest estimate. But that estimate requires unusually rapid capital accumulation, consistent with our estimates of the recent gap -- but probably not his -- and, more importantly it ignores the prospects of further energy cost changes and their effect. Accounting for energy price developments and assuming capital growth to remain the same as the last two years results in a growth rate of potential output which is the same as that we have observed for the last two years, 3.0 percent. Finally, allowing for energy price developments and a more historically normal pace of capital growth of 4.1 percent under peak conditions yields an estimate equal to Clark's of 3.5 percent per year. We regard a 3.5 percent growth rate of potential output to be a reasonably optimistic estimate of the potential growth rate when the recent response of investment to energy cost changes is considered.

Since the current GNP gap is quite small compared to alternative estimates, and since our investigation of the growth rate of potential suggests it will grow at a maximum of about 3.5 percent, we conclude that the economy will achieve full-employment and peak operating performance within a year if the actual growth rate of real output since 1974 continues. Unlike other studies of potential output, we conclude that more stimulative monetary or fiscal policies are neither necessary or desirable.

Conclusion

Our measures show the economy to be producing over 97 percent of its potential at mid-year 1977. In addition, our measures show potential output to have grown at about a three percent rate during the recovery. The rate of growth of potential GNP for the remainder of the decade is about 3.5 percent, at most. These findings stand in stark contrast to the mainstream view. Several recent studies have shown the basis of this conventional view to be seriously flawed. Nonetheless, most observers are reluctant to alter their views on U.S. economic performance or the potential output growth rate after 1973, apparently due to the power of historical extrapolation.

Our conclusions follow from a theoretical analysis of the role of energy resources and the relative price of energy in the production process of the U.S. economy. The empirical analysis of the relationship of aggregate production to resource employment supports the theoretical conclusions. The analysis provides empirical estimates of production function parameters which allow the quantification of effects of changes in the supply of potential resources on output possibilities. These estimates go well beyond the specificity allowed by other studies, which either fail to take resources such as capital or energy into account, or which fall back on standard assumptions about some of the relevant coefficients.

Our potential output series reflects our earlier conclusions and those added here. In particular, the large increase in the relative price of energy led to a change in the pattern of resource use which constitutes efficient production, changing the demand for all resources, but, most importantly, permanently reducing the productivity of existing labor and capital resources. Increases in the cost of energy over the last two years, and further increases yet to come during the remainder of the decade, continue the negative energy cost effect on potential output but to a lesser extent. The direct productivity effect of the higher cost of energy is compounded by an indirect effect temporarily reducing the rate of capital accumulation. The reduced incentive to invest was shown to be due to both the reduced productivity of the services of existing capital and its increased replacement cost. These conclusions are supported by the unusually sluggish growth of capital since 1974.

We have argued that stimulative demand management policies are both unnecessary and inflationary, and that at potential output the federal budget shows a very large deficit. The economy will very likely achieve its potential output rate within a year with only moderate growth. Carlson (August 1977, Review) has verified that, rather than a high employment balanced budget in 1977, as would be the case if the old CEA measures were correct, the high-employment deficit is currently about $20 billion. Thus, within a year it will become virtually impossible to postpone critical fiscal decisions concerning the means of permanent financing of the existing and/or desired role of the federal government in a markedly changed American economy.

Footnotes

1/ See Business Week, (June 9, 1973), pp. 76 - 77.

2/ Ibid., p. 77.

3/ See Roger Brinner, "Potential Growth to 1980," Otto Eckstein et. al., Economic Issues and Parameters of the Next 4 Years, Lexington, Massachusetts: Data Resources, Inc., Economic Study Series, 1977, pp. 9 - 17.

4/ See especially Denis S. Karnosky, "The Link Between Money and Prices - 1971-76," Federal Reserve Bank of St. Louis, Review June 1976, pp. 17 - 23.

5/ References to our May and June papers throughout are: Robert H. Rasche and John A. Tatom, "The Effects of the New Energy Regime on Economic Capacity, Production, and Prices," and "Energy Resources and Potential GNP," Federal Reserve Bank of St. Louis Review May and June, 1977, pp. 2 - 12, and pp. 10 - 23, respectively.

6/ Brookings Papers on Economic Activity, 1:1977, pp. 11 - 47.

7/ This contrasts with his opinion in 1973 as cited above.

8/ The derivation of this specification is indicated in our June Review paper. Note in particular that it assumes that the aggregate demand for energy is on a demand curve with unitary elasticity with respect to both output and relative price. This is a relatively common assumption when working with time series data generated over annual intervals. On the other hand, this condition is less likely to be satisfied over shorter time intervals such as a quarter. Under such circumstances, it is more common to specify partial adjustment models which have smaller impact elasticities. For a discussion of the biases in our estimates of the output elasticities which result from impact elasticities which are smaller than unity, see Appendix II of our June paper. In addition, partial adjustment mechanisms for factor demands, such as that specified by M. I. Nadiri and S. Rosen, "Interrelated Factor Demand Functions," American Economic Review, September 1969, pp. 457-71, would suggest that the above equation may be misspecified by the omission of lagged values of all factors. It is not clear that such a source of potential specification error would systematically bias our regression coefficients in one direction.

9/ See John C. Musgrave, "Fixed Nonresidential Business and Residential Capital in the United States, 1925-75," Survey of Current Business April 1976, pp. 46 - 52.

10/ The minor differences from the results in Appendix III of our June article arise due to BLS data revisions and revisions in the GNP accounts.

11/ The constrained estimate yields a measure of the output elasticity of labor equal to 64.3 percent and quarterly trend growth rate of .41 percent. The Durbin-Watson statistic for the equation is 1.91, the estimate of rho is .78, and the standard error of the regression is .0077.

12/ The standard error of the equation below is identical to that using the unemployment rate to four decimal places.

13/ The error pattern without any adjustment indicated a smooth phasing in and out of the shift over a four quarter period, thus, the dummy variable was allowed to increase from zero to one in steps of one-fourth and conversely to decrease at the end of the period in the same way. Of course, this phasing in and out led to a reduction in the standard error of the hours per worker equation.

14/ The weakness associated with such an hours per worker equation, especially with the adjustment for the unusual developments in the 1960s, has also been noted by Perry (1977, p. 31). He used a similar equation for hours per worker in the nonfarm business sector.

15/ A description of Clark's method for deriving the full-employment unemployment rate and the potential labor force may be found in Peter K. Clark, "A New Estimate of Potential GNP," Council of Economic Advisers, 1977; processed.

16/ See Ronald J. Talley, "Some New Estimates of Potential Output," forthcoming in American Statistical Association, 1977 Proceedings of the Business and Economic Statistics Section.

17/ See Walter W. Heller, "Productivity and GNP Potential," Wall Street Journal, June 29, 1977.

18/ See Albert J. Eckstein and Dale M. Heien, "Estimating Potential Output for the U.S. Economy in a Model Framework," Achieving the Goals of the Employment Act of 1946-Thirtieth Anniversary Review, U.S. Congress, Joint Economic Committee, 94th Cong., 2nd sess., December 3, 1976, pp. 1 - 25.

19/ See the comment by Otto Eckstein, Brookings Papers on Economic Activity,(I:1977, p. 53.

20/ G. Cain & H. Watts, eds., "Income Maintenance and Labor Supply," (New York: Academic Press, 1973).

21/ The model by Eckstein and Heien (1976) suggests a slight positive effect on the labor supply due to the increased energy cost. However, it is not clear whether they estimate the relevant net effect or one of the components.

22/ Capital embodying different technologies is not differentiated here. Presumably some substitution toward less energy intensive processes would stimulate demand for certain kinds of capital goods while reducing that of other capital and the total demand. Also, the analysis follows the usual convention in assuming the real rate of return demanded by lenders and equity owners and that used by investors in discounting income streams is unchanged.

23/ This result is demonstrated in our May (1977) Review article.

24/ The graphical analysis is adopted from Leonardo Auernheimer, "Rentals, Prices, Stocks and Flows: A Simple Model," Southern Economic Journal, July 1976, pp. 956-59.

25/ If the long-run supply price of new capital goods is independent of the output rate, the result is unambiguous as both the price and rental price of capital goods are higher in the new steady-state solution.

26/ A discussion of the unusual behavior of non-residential fixed investment in the recent past may be found in Jai-Hoon Yang's, "A Guide to Capital Outlays in the Current Recovery," Federal Reserve Bank of St. Louis, Review, February 1977, pp. 2 - 7.

27/ A review and evaluation of recent energy regulation in the United States may be found in Paul W. MacAvoy, ed., Federal Energy Administration Regulation, Washington, D.C.: American Enterprise Institute for Public Policy Research, 1977.

28/ In the levels form, the equation has a R^2 of .98 and standard error of .012. The price of crude oil coefficient, .45 (t = 5.65), is in agreement with that reported above. The rho statistic has a value of .97. Thus, the first difference form is cited in the text and used below.

29/ This assumption is also made by Perry (Table 14, p. 45) and may contribute to his unusually rapid rate of growth conclusion.