Foreword

This volume contains the papers presented at the October 7, 1977 conference on "U. S. Productive Capacity: Estimating the Utilization Gap," held in St. Louis, Missouri. The conference, cosponsored by the Center for the Study of American Business and the Federal Reserve Bank of St. Louis, examined the current and projected estimates of U.S. productive capacity and utilization. Appropriate measures of the gap between productive capacity utilized and full productive capacity are important to the development of appropriate economic policy.

The three basic papers were presented by George Perry of the Brookings Institution, Peter Clark of the staff of the Council of Economic Advisers, and by Robert Rasche and Jack Tatom of Michigan State University and the Federal Reserve Bank of St. Louis.

An economic policy address was given by William Nordhaus, a member of the Council of Economic Advisers. A paper by James Ragan of Kansas State University on projections of capacity utilization is also included in the Supplemental Papers section of this volume. Discussion papers were presented by Pham Chi Thanh of American University, Laurence Meyer of Washington University, and Frank deLeeuw of the Congressional Budget Office.

POTENTIAL OUTPUT:
RECENT ISSUES AND PRESENT TRENDS

George L. Perry

Potential output measures the real GNP that would be associated with operating the economy at some specified level of labor utilization. The concept offers answers to two basic types of questions: what would be the level of GNP if unemployment was at a specified level? (Or what would unemployment be if GNP were at some specified level?) And what will unemployment be at some point in the future if GNP grows at some specified rate? (Or what will GNP be if some specified unemployment target is achieved at some point in the future?) In the process of developing the concept of potential and providing the needed estimates for answering these questions, we have gained a number of insights into the cyclical characteristics of the economy. Okun's law, which summarizes many of these characteristics in linking marginal output to marginal changes in unemployment rates, is probably the most robust macroeconomic relationship yet developed.

Despite the general success of the original potential concept and related relationships such as Okun's law, several developments of the 1970s have cast doubt on traditional methods of measuring the nation's

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economic potential. First, the changing composition of the labor force, and more dramatically, of the unemployed impinge on potential output measures in two distinct ways: Labor input measured in efficiency units has been diverging from labor measured by a head count; and a constant unemployment rate, tradionally used as a benchmark for measuring potnetial output, has moved noticeably away from measuring a constant degree of labor utilization measured in efficiency units. In the past, I have addressed both these issues of labor force and unemployment composition, and they are both incorporated in recent official analyses of potential by the Council of Economic Advisers. Second, the slowdown in the growth of the capital stock -- which has been particularly marked since 1973 once an allowance is made for investment that is going to meet environmental requirements -- has raised anew the question of whether explicit attention to the size and growth rate of capital is needed in estimating potential output. The most recent official CEA estimates are based on analysis by Peter Clark[1/] that takes account of variations such as these in capital stock growth. And the recent slowdown in the growth of the capital stock, measured after deducting an estimate of investments going to pollution abatement, is an important source of the slowdown in potential output growth estimated by CEA. Third, the dramatic rise in energy prices has caused some analysts to make estimates of potential that are seriously affected by this energy price explosion. The most notable examples of this new wrinkle are the papers by Robert Rasche and John Tatom that have been published in the Federal Reserve Bank of St. Louis Review.[2/]

Finally, my colleague, Edward Denison has called my attention to the importance for potential output measures of changes in the environment in which businesses operate -- including the rise in crime, pollution abatement regulations, and regulations covering safety and health practices. His research in this area is still underway.

In this paper, I will report on some work that deals explicitly with the first of these departures from tradition and that indirectly supports the last of these as well -- that is, the demographic issues and the Denison issues. But before getting into this analysis, I want to turn to why I am ignoring explicit attention to the capital stock, although ideally I would like to integrate it into the analysis. And why I am ignoring the impact of energy prices, and think that giving that development a prominent role in modifying potential output measurements is mistaken.

The Case Against Using Capital

It is hard to argue that capital should not be included in estimating potential output because everyone knows it belongs in the calculation. Back in the 1960s, the same CEA that introduced potential output into the mainstream of policymaking and debate also introduced the investment credit in order to stimulate capital formation. If capital is ignored, it is for a simple pragmatic reason: one cannot find an important or statistically significant role for capital in a freely estimated aggregate production function or any equivalent relation that one might use in estimating potential output. Although this negative result is well known, I thought I would try again using the newly-developed data on the capital stock from the Bureau of Economic Analysis. I tried, in turn, several versions of the capital stock including the total stock, equipment separately, the stock with estimated expenditures for pollution abatement subtracted, and the stock for manufacturing alone and for the total nonfarm business sector. None of these worked.

This left me with a choice of research strategies. Constrain the capital stock to play some specified role in determining potential output. Or see how well the trend in labor productivity can be explained by taking account of cyclical factors and changes in labor force composition. Several considerations led me to opt for the latter approach. Any capital stock series must rest on assumptions about retirements of physical capital from the stock. We probably do not know enough about these retirements and about whether they proceed smoothly or whether they, in turn, depend on current rates of investment. The degree to which the capital stock is utilized at any point in time is not only hard to measure but is a very uncertain concept at bottom. Nobody can ever explain how we had enough of a capital stock to produce the output we did during World War II. More generally, since it is the flow of productive services from the capital stock that we presumably want to measure, we have to deal with the fact that the flow of services from a given stock can be expanded simply by expanding the hours over which we utilize it. Thus moving to double-shift operations doubles the effective capital stock without any new investment taking place. A department store that starts staying open from 6 to 9 in the evening adds a third to the effective capital stock of that operation. This consideration is particularly troublesome when we try to measure potential output since we are then interested in the effect of the capital stock at some relatively high rate of production -- precisely the situation in which a more intense utilization of the existing stock might be expected. When the economy reached a 4 percent unemployment rate during 1966, the level then defining its potential, available measures of capacity utilization in manufacturing reached levels substantially higher than we have observed since then, despite achieving even lower unemployment rates. If these utilization figures are meaningful, they indicate that the available services from the capital stock are quite expandable and are not closely linked to the level of the unemployment rate.

Finally, even if we were ingenious enough to integrate these complexities into our concept of capital and its relation to potential output, we would still have to deal with the fact that the capital stock that interests us is not today's, but the stock that will exist at the time potential is achieved. The measured capital stock systematically grows faster as the economy expands toward potential and more slowly during recessions when actual output recedes from potential. To decide what potential output will be in 1981, we would have to forecast the levels of investment that would take place each year in a move to potential and integrate these into the analysis. After recession, when the economy is well below its potential, the capital stock always looks low relative to a trend line estimate of potential output.

Of course, against these complications that arise from trying to utilize the capital stock in potential calculations, we have to weigh the possible improvement we could get if we correctly measured the relevant stock and its effect on labor productivity at potential. Clark has made a careful attempt at doing this and we may have to wait until potential is approached to know which research strategy gives more accurate answers.

The Case Against High Estimates of Energy Price Impacts

The sharp increases in energy prices of recent years led to large reductions in potential output under certain restrictive assumptions about how energy and output are related. The simplest of these assumptions, and the one utilized by Rasche and Tatom, is that output in the business sector is governed by a Cobb-Douglas production function with capital (K), energy (E), and labor (L) as inputs and a disembodied productivity trend growing at the rate r:

$$(1) \qquad Y = Ae^{rt} L^{a} K^{b} E^{c}, \quad a+b+c = 1$$

In this assumed production relationship, the output elasticity of energy is one and its price elasticity is minus one. That is, doubling output will double energy demand while doubling the relative price of energy will cut the amount demanded in half. The first of these propositions seems entirely plausible. The second very unlikely. Yet it lies behind the proposition that the rise in energy prices has substantially reduced potential output.

Measured by the wholesale price of energy to users, the relative price of energy rose 57 percent between 1973 and 1976. If we believe the elasticity of -1.0, and apply it to all energy used in the country, our energy use should be only 64 percent of its former level (relative to trend and adjusting for output effects, both of which are relatively small by comparison). We should have no oil-import problem and should probably be exporting oil to the rest of the world -- unless they too had price elasticities of -1.0 for their demands.

Statistics on energy used in production, as opposed to use by government consumers, are hard to get and Rasche and Tatom resorted to using price data rather than quantity data in their production function. Since, under the Cobb-Douglas assumptions, energy use is given by

(2) $$E = cYP_E^{-1} ,$$

where P_E is the relative price of energy, their price series proxied for the unobserved quantities of fuel use. Up to 1973, there was not much variation in the relative price of fuel, so it was probably hard to view the resulting estimates very critically. But what has happened to energy use since 1973 shows the model is wildly unrealistic. And therefore so are its implications for potential output.

I have made some estimates of how much business has curtailed energy use in response to the increase in fuel prices since 1973. An accurate total of business fuel consumption is hard to get, but I was able to assemble time series covering about 60 percent of the total.

The main omissions were commercial uses of petroleum for heating and transportation. I estimated the following relationship over the period 1949-1973,

$$(3) \qquad \ln \frac{E}{Q} = A + \rho_1 t + b_1 \ln U$$

where E is my series on BTUs used by business, Q is gross business product, U is utilization measured as the ratio of Q to potential Q,[3/] and ρ is an estimate of the annual trend in $\frac{E}{Q}$. This equation says that, through time, energy per unit of output has displayed a trend of ρ_1 per year. While at a point in time, energy use will be $(1+b_1)$ percent greater for every one percent additional output that is produced.

Table 1 shows three sets of coefficient estimates for this equation, the estimates differing according to whether the utilization term is included and whether the equation is adjusted for serial correlation. They also differ in the time period used for estimating since data on U were not available before 1954. The estimates indicate a trend decline of 1.3 to 1.6 percent per year in energy per unit of output. In the two equations that have it, the coefficient on the utilization term indicates a cyclical elasticity of energy use with respect to output of 1.3 to 1.4. However, the estimate of b_1 has a low t-statistic in both equations 4a and 4b and equation 4c may be more reliable.

The relative price of energy trended down through most of the estimation period and its effect cannot be separated from the trend in energy per unit of output. But the post-sample prediction errors from the Table 1 equations provide estimates of how much energy use has been

Table 1. Estimated Equations for Energy Per Unit of Ouput, Private Business Sector[4/]

Equation number	Coefficients			Data Period	$\bar{R}^2$	D.W.	S.E.	rho	Percent errors	
	Constant A	Time ρ_1	Utilization b_1						1973 prediction	1976 forecast
(4a)	2.91 (9.82)	-0.01278 (-8.6)	0.4413 (1.43)	1954-73	0.805	0.9	0.034	-	-3.0%	-5.9%
(4b)	3.04 (9.4)	-0.01266 (-5.9)	0.3111 (0.93)	1954-73	0.877	1.3	0.027	0.561	-3.8%	-7.0%
(4c)	3.46 (115.8)	-0.01557 (-8.0)	-	1949-73	0.929	1.9	0.031	0.641	-2.1%	-7.0%

reduced as a result of the post-1973 price changes. The ratio of energy to output in the business sector declined by 10.2 percent between 1973 and 1976. Equations 4a, 4b, and 4c in Table 1 predicted declines of 7.3, 7.0, and 5.3 percent respectively. Thus my measure of energy use declined by 2.9 to 4.9 percent more than predicted, given the behavior of output over this period. This is the response one can attribute to higher energy prices or other, unspecified factors, using the equations of Table 1. Since the relative price of energy rose by 57 percent over this period, the indicated price elasticity for business use of energy is between 0.05 and 0.085.

Low as these estimates are, they probably still overstate the true amount of energy saving that has occurred thus far. The Table 1 equations assume a constant trend through 1973 in energy per unit of business output. In fact, the nearer to 1973 one starts to estimate the trend, the steeper the estimated decline rate is. If the decline that would have occurred without the price explosion was greater than the Table 1 equations indicate, the extra decline that can be attributed to the price explosion is correspondingly smaller.

Other studies, based on long time series and on cross-sections, have estimated higher price elasticities than these. The absence of any spectacular change in the relative price of energy before 1973 would make any statistical estimates from time series up to that time uncertain; while cross-sections may reflect differences other than just the price of energy, and may not be useful for predicting the response to a change in price in the U.S. The present estimates come from the first opportunity to observe the response of use to a large change in price. It may be that three years is much too short a period to observe long-term effects; with more time, energy use may respond further. And it is probably true that total use of energy, as opposed to business use, is more price elastic. But it is business use that is relevant for potential output calculations. And it is the response to date and over the next few years that is relevant, at least for stabilization problems, not the response that may eventually occur over a period of many years when the capital stock -- and eventually the geographical distribution of the population and life styles -- have all had a chance to evolve.

Effects on Potential Output

Knowledge of the quantity of energy conserved permits some guess at the decline in labor productivity and potential output that resulted from higher energy prices without making restrictive assumptions about the form of an aggregate production function. Valued at 1976 prices, the estimated energy saving of 2.9 to 4.9 percent was worth \$2.8 billion to \$4.8 billion. Reducing this to 1973 relative prices, the range is \$2.0 to \$3.4 billion. Since the most profitable substitution of other factors are marginal at the old price and the least profitable are marginal at the new, the midpoint is appropriate, providing a range of \$2.4 billion to \$4.1 billion for the value of other inputs substituted for energy. Even if business is assumed to have accomplished all this saving by substituting labor for energy, not much extra labor could have been used in this process. \$4.1 billion is 0.5 percent of employee compensation in the business sector. $2.4 billion is 0.3 percent. Since an unknown amount of the substitution must involve capital as well as labor, the added labor input would be smaller still. If we assume the substitution is proportional to the usual two-thirds, one-third split of shares between capital and labor, the estimate of labor substituted falls to 0.2 percent to 0.33 percent. Finally, some part of the energy saving must have involved no substitution of other inputs at all: lowering thermostats to 68 degrees in winter and raising them to 75 degrees in summer or turning out every other light in hallways are obvious examples, but there must have been many less obvious examples of "waste" that were eliminated only after the OPEC crisis made firms more energy conscious. The amount of energy saving that involved labor substitution must be smaller than the total energy saving by the amount of all this "costless" conservation. I know of no way to pin down the answer more accurately; but on the basis of the evidence here, it seems unlikely that higher energy prices have caused more than a 0.2 percent loss of labor productivity and potential output between 1973 and 1976.

It seems likely that there will be more energy saved in the longer run. But it also seems plausible that any growing conservation of energy will come disproportionately from substituting capital rather than labor for energy. If the price elasticity of energy use after ten years is substantially greater than after three years, it is presumably because the capital stock will be changed much more over the longer period. Thus, in response to higher energy prices, we would predict an unusually large amount of investment with greater confidence than we would predict an unusually slow growth in labor productivity.

Don't Higher Prices Hurt?

The apparent paradox in all this is that the inability to substitute labor for energy has kept potential output from being affected by the increase in energy prices. If the substitutability assumed by Rasche and Tatom were in fact available, our potential output would have fallen just as they described. The answer is that our economic welfare has been reduced by OPEC. Our consumption possibilities for other goods and services are smaller by the amount that our fuel bills are larger. Substitution would help us reduce the size of this fuel bill, but the possibilities for substitution are slight, at least in the short-run, as the low response of energy use to date has shown.

Since much of the added revenue from higher energy prices has gone to U.S. producers, it gets complicated to figure out exactly who is worse off and by how much. Furthermore, our exchange rate may have been affected by OPEC's price increase and the subsequent spending and investment decisions of oil producers, thus altering our terms of trade with the rest of the world and further muddying the full calculation of what it has cost us. But for the present purpose, we are not after such a measure. For calculating potential output effects, we need to know how much labor productivity has been affected. And the answer is the effect, thus far at least, is negligible.

Potential GNP Estimated

For the reasons I have just described, my own recent estimates of potential output are made without explicit attention to the capital stock or energy prices.[5/] An examination of the residuals from my estimating equations should indicate whether these, or other, omissions are inappropriate.

I define the potential path of the economy as the trend line of real GNP passing through actual real GNP in mid-1955 and growing at a rate that would hold the weighted unemployment rate at its mid-1955 level. This is similar to the long-established benchmark for potential originally presented by Okun, except that the path is defined by constant weighted unemployment rather than the conventional aggregate unemployment rate. Weighted unemployment measures underutilized labor in efficiency units rather than bodies. As such it is a better summary measure of labor market tightness than conventional unemployment. But it is not intended to define a "noninflationary" level of labor utilization. That is another, and more complicated, matter.

Over the past 15 years, the conventional unemployment rate along the potential path has drifted upward, from 4.1 percent to 4.9 percent in 1976. The main reasons for this are the declining proportion of high-weight adult males in the work force and the rising relative unemployment rates of low-weight young workers of both sexes. The drift in conventional unemployment rates along the potential path is very close to the drift along the CEA's path, which is based on a similar treatment of the labor force.

The economy's potential labor force is calculated using participation rate equations for each of 14 demographic groups in the total labor force. These equations account for cyclical variability in the labor force of women and younger men. They also provide estimates of the trends in participation rates along the potential path. Labor input is measured by weighting the employment and labor force in each of the 14 age-sex categories by relative wages and summing them. Potential weighted labor force and weighted employment are obtained by adjusting the actuals to potential using the cyclical components of the participation rate equations. An equation estimating average hours worked per year, again with a cyclical and trend component, provides estimates of potential average hours. Multiplying this by potential weighted employment each year gives potential weighted total hours, the basic measure of potential labor input in the analysis.

Weighted labor productivity is defined as labor input divided by output. Since the labor input measure is already weighted to take account of average productivity differences among workers in different demographic groups, weighted productivity is already cleansed of this source of cyclical variation and trend in conventional productivity measures.

The relationship between labor input and output in the business sector provides the basis for examining the behavior of weighted productivity and estimating a potential output path for the economy. The basic model starts out with the proposition that weighted labor productivity grows exponentially along the potential path:

(5) $$\frac{\overline{Q}}{\overline{H}} = Be^{rt} ,$$

where Q is output in the business sector, r is the annual growth rate, t is a time index, and the bars over variables indicate potential values. This can be modified to allow for a break in the growth trend:

(6) $$\frac{\overline{Q}}{\overline{H}} = Be^{(r_1t_1+r_2t_2)} .$$

Cyclical deviations of productivity from its trend are expressed by

(7) $$\frac{\overline{Q}}{Q} = (\frac{\overline{H}}{H})^{\beta} ,$$

where $\beta > 1$ if, as expected, productivity is higher the higher the level of actual hours or actual output relative to potential. Previous work has shown that some lags exist in this cyclical relation, and they are allowed for by modifying 7 to

(8) $$\frac{\overline{H}}{H} = (\frac{\overline{Q}}{Q})^{\delta}\left[\frac{\overline{Q}/Q}{(\overline{Q}/Q)_{-1}}\right]^{\rho} .$$

Combining equations 6 and 8 to eliminate $\overline{Q}$ leads to the basic equation used for statistical estimation.

In the original analysis, some alternative specifications were tried and residuals were examined to determine whether a break in the time trend was important in modelling potential. The evidence only slightly favored the hypothesis of a trend break and two alternative estimates of potential output were made, one based on a constant trend in weighted productivity over the 1954-1976 interval, the other with a break in that trend in 1969.

Now, however, on the basis of the analysis that Edward Denison is currently conducting, the case for a break in the trend seems compelling. Denison is measuring the effect on productivity of business costs or expenditures -- those associated with dishonesty and crime, with compliance with health and safety requirements, and with pollution control -- he finds productivity growth has been eroded since the late 1960s. When Denison's final estimates are available, it will be possible to integrate them carefully into an analysis such as the present one.[6/] But for now, they lend independent support to the estimates that allow for a break in the weighted productivity trend.

The equation estimated with a break in the productivity trend in 1969 is

$$(9)\quad \log\left(\frac{\bar{H}}{H}\right)_t = \underset{}{-5.28} + \underset{(13.5)}{0.0179T54} + \underset{(16.5)}{0.651}\log\left(\frac{\bar{H}}{Q}\right)_t$$

$$\underset{(-2.3)}{-0.093}\left[\log\left(\frac{\bar{H}}{Q}\right)_t - \log\left(\frac{\bar{H}}{Q}\right)_{t-1}\right] \underset{(-3.3)}{-0.0237D74} - \underset{(-1.5)}{0.0019T69},$$

SEE = 0.0062, D.W. = 1.77, estimation period is 1954-1976.

In this equation, T54 and T69 are the annual time trend dummies starting in 1954 and 1969 respectively. They indicate an annual trend in weighted productivity of 2.75 percent through 1968 and 2.46 percent thereafter. D74 is a dummy for the year 1974 when productivity experienced its largest residual. While a variety of observations about business behavior that year led me to use the dummy, its only noticeable effect is to reduce the size and importance of the lagged adjustment term. The residuals from the equation for 1973, 1975, and 1976 are only 0.2, 0.3, and 0.3 respectively, indicating only a slight underprediction of productivity and no trend toward a growing error.

The final estimate of potential output that arises from combining my potential labor input estimates with the trend in potential weighted productivity are summarized in Table 2. In calculating these estimates, labor input and output outside the business sector are assumed the same at actual and potential.

Actual GNP in 1976 was estimated to be 8.3 percent below potential. In the 1976-81 period, potential is projected to increase at an average rate of 3.88 percent, just slightly slower than in the 1970-76 period and noticeably faster than in the previous intervals covered by this study. The projected 2.1 percent annual growth in the labor force is noticeably slower than the 1970-76 average and slightly slower than in the 1965-70 period. However, as a comparison of the last two lines in the table show, the difference between conventionally measured productivity and weighted productivity narrows sharply in the projection period. Where potential output growth was slowed over the past decade by the changing demographic composition of the work force, in the period ahead, as a result of the maturing of the baby boom, it is not.

While the impact of energy prices on potential has been shown to be slight, a very modest adjustment to the point estimates presented

Table 2. Profile of Changes in the Economy at Potential, Selected Intervals, 1955-81 (annual rate of growth in percent)

Sector and economic measure	1955-60	1960-65	1965-70	1970-76	Projected 1976-81
Total economy					
Labor force	1.01	1.29	2.17	2.39	2.08
Employment	0.97	1.23	2.14	2.31	2.07
Real GNP	3.49	3.49	3.53	3.91	3.88
Business Sector					
Employment	1.21	1.11	2.30	2.87	2.07
Total hours	0.95	0.84	1.41	2.41	1.53
Output	3.62	3.42	3.64	4.34	3.92
Output per hour	2.65	2.56	2.19	1.96	2.35
Output per weighted hour	2.79	2.79	2.67	2.48	2.49

here can be made to allow for it. Reducing the estimate of the 1976 output gap by 0.2 percent and the annual growth rate of potential in the 1976-1981 interval by 0.1 percentage point is about all the adjustment that seems appropriate. This brings the current annual growth rate of potential to 3-3/4 percent. The main implication of this analysis for the capital stock is not that its present size calls for a downward adjustment of potential estimates, but that we should expect strong business investment demand and a rapid expansion of the stock if the economy grows enough to approach its potential level over the next few years.

Footnotes

1/ Peter K. Clark, "A New Estimate of Potential GNP (Council of Economic Advisers, 1977; processed).

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

3/ Potential Q is taken from the analysis presented later in this paper. It could just as well be taken from the CEA estimates as there is little difference between the two over the relevant period.

4/ The estimated coefficients correspond to Equation (3) in the text. t-statistics are given in parentheses.

5/ The analysis is presented in greater detail in George L. Perry, "Potential Output and Productivity," Brookings Papers on Economic Activity, 1:1977.

6/ The analysis will be presented in a forthcoming issue of the Survey of Current Business.

POTENTIAL GNP IN THE

UNITED STATES, 1948-1980

Peter K. Clark

Introduction

The concept of the output attainable by the economy if resources were fully utilized has interested economists for many years. This measure of maximum sustainable output, usually called "potential GNP," has been a useful tool for analyzing policies designed to bring about the full utilization of labor and capital resources.

The potential GNP measure that gained the widest recognition was first proposed by the Council of Economic Advisers in 1962.[1/] After making a number of calculations relating the overall rate of unemployment to constant-dollar GNP, it was determined that a reasonable estimate of the GNP attainable at 4% unemployment equaled actual GNP in mid-1955 and grew at a 3.5% annual rate thereafter. Between 1962 and 1976, CEA revised its potential GNP estimates a number of times; the annual growth rate for potential output was finally pegged at 4.0% for the period 1968-1975 when trend output was thought to be rising rapidly relative to the unemployment rate. Still, in 1976, a judgmental variant of CEA's original procedure[2/] was still being used to determine potential

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output. Potential and actual GNP were still defined to be equal in mid-1955, and the benchmark unemployment rate was still 4.0%.

Research on potential GNP from 1964 to 1974 produced a number of different views on the best estimation technique, but very little disagreement about the estimates themselves.[3/] All of the results were similar to the CEA estimates or even somewhat higher. Perry [12], for example, used a weighted labor input measure to compensate for the changing composition of the labor force, and found that potential output was growing at 4.3% per year in the early 1970's, or 0.3% higher than the CEA estimate of 4.0%.

However, several aspects of the economy's performance between 1973 and 1976 indicated that the maximum sustainable output might be significantly lower than the CEA estimates. First, in 1973 a number of bottlenecks occurred both in primary materials industries and in labor markets which indicated that the economy might have even exceeded the non-inflationary level, rather than being below potential by 2.4% as CEA estimated. Second, shifts in the composition of the labor force toward demographic groups (particularly those aged 16-24) with relatively high unemployment rates indicated that the labor market in 1976 would be much tighter with a 4.0% unemployment rate than it was in 1955. In other words, if a 4.0% unemployment rate was consistent with a stable inflation rate in 1955, it would produce accelerating inflation in 1976.

Third, the productivity slowdown evident in the BLS statistics since the mid-1960's did not seem to be adequately included in the CEA estimate of 4.0% potential growth from 1968 to 1975. Although higher labor force growth offset the poor productivity performance to some extent it was not clear that the sum of these two effects should result in growth of potential a full one-half percent higher than CEA's original estimate for the 1950s. The productivity decline in 1974 was so extraordinary compared with declines observed in earlier recessions that it demanded special attention. The persistence of the low level of productivity in 1975 and 1976 indicated that a permanent setback may have taken place. Such an occurrence would have lowered maximum sustainable output still further.

And finally, the Commerce Department revised its real output series in 1976, shifting from 1958 to 1972 prices. Such a shift could normally be expected to change the observed patterns of growth and to lower measured growth rates. The new data needed to be incorporated into the potential output measure.

For these reasons, in 1976 the Council of Economic Advisers decided to undertake a comprehensive review of the official potential GNP series and the methodology used to derive it.[4/] Using a technique that incorporated the contribution of capital formation to output growth, together with a variable unemployment benchmark rising from 4.0% in 1955 to 4.9% in 1976, a new estimate of potential was calculated.[5/] This paper refines the statistical methodology used to determine CEA's new potential GNP series and updates the estimates with data through the second quarter of 1977.

The new CEA estimate of potential GNP grows 3.5% per year between 1968 and 1976, significantly lower than previous estimates. This result makes the formulation of economic policy harder in one sense, but easier in another. The problem is that lower potential output implies that high employment will generate less output than previously estimated. For the government, this means lower revenues and a smaller budget margin for new programs or tax reductions. On the other hand, lower productivity implies that a smaller increase in output will achieve the same unemployment and capacity utilization targets. If increases in aggregate demand are constrained by low investment or a climate of fiscal conservatism, poor productivity performance is not unambiguously bad.

Disaggregation of GNP

The crucial determinant of the difference between any two historical potential GNP estimates is the rate of growth of productivity. The main question is then: How much has the rate of productivity growth slowed down? The answer is not easy to obtain because productivity varies widely with the business cycle, growing rapidly in expansions in economic activity, and growing more slowly or even falling during recessions. Most of the research reported in this paper was devoted to obtaining good estimates of the trend in productivity growth by careful adjustment for cyclical factors. These cyclically adjusted productivity growth figures are then combined with estimates of factor input to obtain potential output.

The first step in estimating the trend in productivity growth was the division of GNP into four components:

1. Gross Output Originating in the Rest of the World

2. Compensation of Government Employees

3. Gross Housing Output

4. Private Nonresidential Output

Gross output originating in the rest of the world, or GNP minus GDP, was an obvious candidate for exclusion from the productivity estimates because this contribution to GNP is generated by investments outside the U.S., and should not respond to domestic inputs of labor or capital.

Compensation of government employees is the only measure of government output in the national income and product accounts. This component is deflated by an index of salaries of government workers, which implies that real output of the government sector is a weighted average of government employment. Therefore, productivity for the government sector is weighted employment divided by employment, and productivity growth is defined as zero in the National Income and Product Accounts. When measuring productivity growth, it is reasonable to exclude government output so that variations in the ratio of government to total employment do not affect the productivity calculations.

Segregation of housing output into a separate category was based on the possibility that the real return from residential capital and nonresidential capital might be different. In theory, such a disparity should be only temporary, but in the actual analysis, it was thought that the fixed nonresidential capital stock measured by the Commerce Department was only a proxy for non-labor inputs to private production. Since housing was easy to exclude, it seemed worthwhile to do so.

Another important reason for excluding these three sectors is that their output is not related to the domestic business cycle. If unemployment is high and capacity utilization low, government output, the imputation to the residential capital stock, and gross product originating in the rest of the world are not necessarily low. Therefore, potential and actual output can be assumed equal in these sectors.

Private nonresidential output, the residual in GNP after (GNP-GDP), compensation of government employees, and output attributable to the residential capital stock have been subtracted, corresponds closely to many economists' preconception of private sector output, produced by capital and labor. It is this output which is most closely studied, and for which productivity estimates will be made.[6/]

Potential and Actual Capital Input to the Private Nonresidential Sector

Productivity is a ratio of output to input; real output for the private nonresidential sector may be derived by subtraction, as described in the last section, but the corresponding capital and labor inputs must be estimated. Capital input was taken to be an estimate of the effective private fixed nonresidential capital stock multiplied by an estimate of capacity utilization. The effective capital stock measure used was the B.E.A. gross stock of private nonresidential capital, adjusted for investment in pollution abatement equipment.[7/] Quarterly data were linearly interpolated from annual data; projections of capital stock were derived from an investment forecast in which the ratio of nonresidential fixed investment to real GNP rises to ten percent by 1980. Six percent of fixed investment was assumed to be for pollution abatement throughout the forecast period. Annual averages of the capital stock series are given in Table A-1.

The newly-revised Federal Reserve Board manufacturing capacity utilization rate[8/] was taken as the starting point for estimating the degree of capacity utilization for the private nonresidential sector. However, since output in manufacturing is much more cyclical than private sector output as a whole, the cyclical variation in the FRB manufacturing index must be reduced. This was accomplished by multiplying the difference between 87.5 and the Fed index by 0.5, the approximate ratio of the percentage standard deviation around trend for private nonresidential output to the percentage standard deviation around trend for manufacturing output. If the ratio of utilized capital to output is fixed in the short run, such an approximation is reasonable.

The potential capacity utilization rate of 87.5% was chosen because it was this rate that was reached in mid-1955, early 1968, and all of 1973, all periods when it is generally considered that output was near its potential level. If there were a close relationship between changes in the rate of inflation for private nonresidential output (or the profit rate) and measured capacity utilization, it would be appropriate to estimate the relationship, and define "potential" capacity utilization as that rate which resulted in non-accelerating prices. However, in the absence of such a "Phillips curve" for capital, 87.5% is a reasonable benchmark.

Potential and Actual Labor Input to the Private Nonresidential Sector

Extensive data on employment and labor force require a much more elaborate set of calculations for the estimation of private labor input. The labor input measure that was constructed tried to adjust for the productivity of different groups of workers by dividing the labor force into four age categories (16-19, 20-24, 25-64, 65+) and also disaggregating by sex. Private employment in each of these 8 categories was obtained by subtracting an estimate of civilian government employment from total civilian employment. Private employment for each group was then weighted by mean weekly earnings for that group in May 1973.[9/] Use of the weekly earnings weights approximates the contribution to production of an employee in each demographic group, including both average hourly earnings and average weekly hours. It would be better to have weights that vary over time rather than one fixed set of weights, but data are not available to construct variable weights. Therefore, the effect of changes in the age-sex weights representing changes in average weekly hours and average hourly earnings is included in the estimated trend terms described later. Rates of growth of weighted and unweighted labor input are shown in Table 1. Although the growth rate of weighted employment is less than the rate of unweighted employment, it is only the change in this difference that explains part of the productivity slowdown since 1966.

Determination of the potential level of labor input requires two extensive calculations. First, the potential labor force must be determined. Then a benchmark unemployment rate is calculated, and used

Table 1

Rates of Growth of Weighted and Unweighted Private Employment, 1948-1976

Time Period	Private Employment[a]	Private Employment (weighted by 1973 earnings)[b]
1948-1955	.58	.61
1955-1966	1.13	.75
1966-1973	1.78	1.38

[a] Civilian employment minus civilian government employment from the Current Population Survey.

[b] Civilian employment minus civilian government employment by eight age-sex groups (16-19, 20-24, 25-64, 65+; M, F) weighted by May 1973 mean weekly earnings, all from Current Population Survey.

to translate potential labor force into potential employment. Since labor input is a weighted sum of employment from eight age-sex groups, levels for potential labor force and the full employment unemployment rate must be determined for each group. Full-employment labor input is then potential employment for each age-sex group reduced by government employment, and then weighted by mean average weekly earnings in 1973.

Potential Labor Force

Potential labor force for each age-sex group is calculated by estimating a cyclical adjustment to labor force participation for that group, and then adjusting actual labor force to full employment labor force using the adjustment. The general form of the labor force participation equation is:

(4) $$\frac{L_{it}}{POP_{it}} = a_i + b_i \cdot U_{t-1} + c_i \cdot t + d_i\, T1_t + e_i \cdot MIL_t + f_i \cdot SCC_t + g_i \cdot AG_t + \varepsilon_{it}$$

Where

L_i = civilian labor force in group i

POP_i = civilian noninstitutional population in group i

U = unemployment rate of men 25-54

t = time

T1 = trend dummy which equals 0 until 1966:4, and then increases 1, 2, 3, 4...

MIL = military employment divided by the civilian noninstitutional population of men aged 16-24

SCC = degree credit enrollment in higher education as a percent of population aged 16-24

AG = proportion of civilian employment in agriculture.

Estimation results for equation (4) are given in Table 2. Using the lagged unemployment rate gives the largest estimate of cyclical variation in the labor force, even though the estimates are smaller than might have been expected. Use of a contemporaneous unemployment rate or a distributed lag on the adult unemployment rate generates lower estimates of cyclical variation. By using the unemployment rate of men 25-54 as a cyclical variable for all groups, the problem of upward simultaneous equation bias is avoided for all groups except men 25-64, where cyclical variation in labor force participation is very small.

The cyclical adjustment for each group was the estimate in Table 2, except for men 25-64, where an insignificant coefficient was estimated even though substantial upward bias due to simultaneity was suspected, and for women 65+, where the cyclical coefficient was insignificant and the wrong sign. The literature on pretest estimators suggests that some of the other cyclical coefficients should be set to zero,[10/] but this was not done. Thus, potential labor force may be a bit high. Of course, if the reaction of labor force participation to long periods of low unemployment is much stronger than its average reaction over the cycle, potential labor force could be underestimated.

In 1976, the estimates in Table 2 imply a potential civilian labor force 1.1 million workers larger than the actual labor force.

Table 2

Estimates of Cyclical Variation in Labor Force Participation Rates by Age and Sex

Estimation interval 1953:1 to 1976:4
(standard errors in parentheses)

Group	a	b	c	d	e	f	g	$\hat{\rho}$	$\bar{R}^2$	d.w
Men 16-19	.411	-.0096	.00040	.00277			1.95	.60	.897	1.81
	(.072)	(.0016)	(.00058)	(.00043)			(.52)			
Women 16-19	.260	-.0059	.00091	.00270			1.27	.57	.934	1.97
	(.080)	(.0018)	(.0006)	(.0005)			(.59)			
Men 20-24	.877	-.0009	.00080		-196.3	-.0039	1.11	.45	.810	1.89
	(.059)	(.0013)	(.00036)		(44.1)	(.0016)	(.35)			
Women 20-24	.427	-.0019	.00111	.00237				.57	.988	1.87
	(.001)	(.0012)	(.00013)	(.00026)						
Men 25-64	.963	-.00017	-.00024	-.00066				.64	.979	1.86
	(.004)	(.0004)	(.00005)	(.0001)						
Women 25-64	.333	-.00025	.00151	.00043				.78	.995	1.91
	(.008)	(.00074)	(.00013)	(.00022)						
Men 65+	.481	-.00183	-.00267	.00138				.80	.991	1.68
	(.015)	(.0013)	(.00024)	(.00042)						
Women 65+	.108	.0003	-.00007	-.00045				.61	.817	2.15
	(.006)	(.0008)	(.00009)	(.00017)						

This figure is only slightly higher than the approximately .9 million "discouraged workers" estimated by BLS for 1976.[11/]

Projections of labor force by group were made with the estimated labor force participation equations. Since they include a cyclical adjustment, the projections are slightly higher than those made recently by BLS. Annual totals for potential labor force are given in Table A-2.

Full Employment Unemployment Rates

The establishment of a benchmark unemployment rate for use in estimating potential output is a difficult problem. If there were a good statistical relationship between unemployment rates and the inflation rate, the vector of unemployment rates by age and sex that yields a constant rate of inflation could be determined directly. Unfortunately, there seems to be no unique relationship between unemployment and inflation, so this simple "Phillips curve" method of estimating an appropriate unemployment benchmark is not available. The picture is further complicated by increases in the proportion of the labor force comprised of young people (aged 16-24) and of adult (aged 25-64) women, which seems to have changed the relationship between the unemployment rates of different age-sex groups. The significant change in the unemployment survey in 1967 also tends to make the determination of an unemployment benchmark which is consistent over time somewhat arbitrary.

The procedure actually used makes the assumption that a 4.0% overall unemployment rate represented full employment in 1955. By looking at the relationship of unemployment rates between age and sex groups in 1955, the eight age-sex unemployment rates that would have yielded a 4.0% overall unemployment rate in 1955 may be determined. It is further assumed that the unemployment rate for men aged 25-54 has remained a stationary indicator of the state of the labor market. The increase or decrease in each group's unemployment rate is estimated using an equation of the form

$$(5) \qquad U_i = \alpha_i + \beta_i * U + \gamma_i * \left(\frac{\hat{LP}_i}{\hat{LP}} \right) ,$$

where

U_i = unemployment rate of age-sex group i

U = unemployment rate of men 25-54 as before,

$\hat{LP}_i = \left(\frac{\hat{L}_i}{Pop_i} \right)$ from equation (4) times Pop_i

$$\hat{LP} = \sum_i \left(\frac{\hat{L}_i}{Pop_i} \right) (Pop_i)$$

The inclusion of the $\left(\frac{\hat{LP}_i}{\hat{LP}} \right)$ term, the relative proportion of group i in the labor force (purged of short-term variations) was based on the idea of partial segregation of labor markets. A relatively high proportion of the labor force in a particular group may make it difficult for members of that group to find satisfactory employment. The coefficient γ_i estimates the change in relationship between the unemployment rate of group i and the unemployment rate of men 25-64. The data used in estimation of equation (5) (and equation (4)) have been adjusted for the change in sampling procedure starting in 1967 by multiplying employment and labor force by ratios obtained in 1966 by BLS using both sampling techniques.[12/] While this adjustment is reasonable for high-employment years, there is no evidence on its accuracy during periods of low economic activity.

Estimation results for equation (5) are given in Table 3 for all eight demographic groups. The unemployment rates for women 25-64, women 65+, and men 25-64 did not exhibit significant change relative to the rate for men 25-54.[13/] The sign of γ was negative for men 65+ indicating the operation of other forces such as Social Security in the labor market for these workers. However, a downward trend was evident, so the equation was re-estimated with a time trend, as shown.

The changes in benchmark unemployment rates by demographic group are illustrated by the results in Table 4. The relative labor force proportion of younger workers (ages 16-24) has risen sharply; equation (5) hypothesizes that this shift in proportions was responsible for the observed change in relative unemployment rates. When combined with estimates of the high employment labor force, these benchmark unemployment rates yeld a benchmark for the overall unemployment rate, also shown in Table 4. The overall benchmark unemployment rate equivalent to 4.0% in 1955 is 5.1% in 1977. It would be an abuse of the term "full employment" to call 5.1% the full employment unemployment rate in 1977, given the high benchmark rates for teenagers, and the fact that the burden of this joblessness is distributed unequally across races and demographic groups. Rather, the estimates in Table 3 are a strong reminder an overall unemployment rate of 3 or 4% would be characterized by a very tight labor market for adults.

Table 3

Estimates of the Relationship of Age-Sex Unemployment Rates to the Unemployment Rate of Men 25-54 (Equation 5)

Estimation Interval 1948:2-1977:2 (standard errors in parentheses)[a]

Group	α_i	β_i	γ_i	Time Trend	ρ	$\bar{R}^2$
Men 16-19	-1.03 (2.33)	1.87 (.152)	208.7 (51.5)		.77	.939
Women 16-19	-7.99 (2.15)	1.31 (.189)	493.8 (60.2)		.76	.936
Men 20-24	- .63 (1.23)	1.92 (.116)	36.5 (19.1)		.70	.947
Women 20-24	.42 (.97)	1.08 (.106)	87.4 (18.9)		.73	.919
Men 25-64	-1.15 (.26)	.95 (.02)	2.7 (.49)		.46	.990
Women 25-64	2.33 (.93)	.77 (.05)	.11 (3.7)		.60	.925
Men 65+	2.37 (.29)	.70 (.07)		-.0072 (.0028)	.49	.786
Women 65+	-1.59 (.82)	.36 (.09)	227.4 (60.5)		.42	.559

[a] Data adjusted for 1967 CPS survey change.

Table 4

High Employment Benchmark Unemployment Rates 1955 and 1977 (percent)

Demographic Group	1955	1977
Women 16-19	10.8	17.7
Women 20-24	6.2	9.1
Women 25-64	3.8	4.3
Women 65+	2.7	1.8
Men 16-19	11.7	14.8
Men 20-24	6.5	7.1
Men 25-64	3.0	2.4
Men 65+	3.6	3.2
Total (Both Sexes, 16+)	4.0	5.1

Note: Unemployment rates assume the survey technique actually used in that year.

4.0% in 1955 and 5.1% in 1977 are in no sense estimates of the lowest overall unemployment rate that does not cause inflation to accelerate. Rather, the time series of unemployment rates generated by the equations in Table 3 is a consistent set of unemployment rates over time generated by the assumption that the unemployment rate of men aged 25-54 is a stationary measure of labor market tightness. The non-accelerating inflation rate of unemployment, or NAIRU, was probably about 0.4 percentage points higher in 1955, and 0.6 to 0.9 percentage points higher today.

The high employment level of labor input is calculated in three steps. First, employment in each age-sex group is estimated by multiplying the potential labor force by one minus the benchmark unemployment rate. Second, civilian government employment is subtracted from these potential employment estimates to obtain potential employment in the private nonresidential sector. Third, potential private nonresidential employment in each age-sex group is weighted by mean average earnings in May 1973 and aggregated to obtain weighted potential labor input.

Cyclical Adjustment of Productivity and the Calculation of Potential GNP

The crucial step in the estimation of potential GNP is the determination of good estimates of productivity at benchmark input levels. If an equation explaining the variation of productivity with the rate of input utilization can be obtained, then a benchmark level of input can be entered into the equation to obtain the level of productivity associated with that benchmark over time.

The basic specification of the variation of productivity with utilization rates used in this study is:

$$(6) \quad \frac{Y_t}{Y_t^P} = \left(\frac{I_t}{I_t^P}\right)^{\beta_0} \left(\frac{I_{t-1}}{I^P{}_{t-1}}\right)^{\beta_1}$$

where

Y_t = real output of the private nonresidential sector in quarter t

Y_t^P = potential value of Y_t in quarter t.

I_t = weighted combination of labor and capital input in the private nonresidential sector in quarter t.

$I_t = (K_t * CU_t)^{1/3} \cdot (L_t)^{2/3}$.

I_t^P = potential value of I_t in quarter t.

K_t = nonresidential fixed capital stock adjusted for pollution abatement investment.

CU_t = Adjusted Federal Reserve Board manufacturing capacity utilization index.

L_t = Earnings-weighted private employment.

If the invertibility condition $|\beta_0| > |\beta_1|$ holds,[14/] (6) $\frac{I_t}{I^P{}_t}$ can be expressed as a convergent series of past $\frac{Y_t}{Y_t^P}$:

$$(7) \quad \frac{I_t}{I_t^P} = \prod_{s=0}^{\infty} \left(\frac{Y_{t-s}}{Y^P{}_{t-s}}\right)^{\alpha_s}$$

Equation (7) may be familiar to many readers as a specification of the lagged response of inputs to output that has been discussed extensively in the literature.[15/] Equations (6) and (7) say that in the long run, the percentage gap between potential and actual input is a constant fraction $1/(\beta_0 + \beta_1)$ of the percentage gap between potential and actual output. In the short run, this fraction is smaller, due to the lagged response of input to output.[16/]

An alternative specification for the cyclical relationship between output and input is equation (7) with a one-period lag:

$$(8) \qquad \frac{I_t}{I_t^P} = \left(\frac{Y_t}{Y_t^P}\right)^{\alpha_0} \left(\frac{Y_{t-1}}{Y_{t-1}^P}\right)^{\alpha_1}$$

Equation (8) is a variant of what is sometimes called "Okun's Law." If we let

$$I_t^G = \frac{I_t^P - I_t}{I_t^P} = \text{percentage input gap}$$

and

$$Y_t^G = \frac{Y_t^P - Y_t}{Y_t^P} = \text{percentage output gap}$$

then (8) becomes:

$$\log (1 - I_t^G) = \alpha_0 \log (1 - Y_t^G) + \alpha_1 \log (1 - Y_{t-1}^G)$$

The approximation $\log (1 + x) \simeq x$ for small x implies:

$$I_t^G = \alpha_0 Y_t^G + \alpha_1 Y_{t-1}^G$$

which gives a percentage input gap as a function of current and lagged output gaps, in much the same way Okun's Law relates an unemployment gap to current and lagged output gaps.

One further assumption besides either (6) or (8) is needed: a specification for the growth in cyclically adjusted total factor productivity:

$$(9) \qquad \log\left(\frac{Y_t^P}{I_t^P}\right) = f(t) + u_t \ ,$$

where f(t) describes how productivity has grown over time. The specification of f(t) was made on an ad hoc basis; namely, total factor productivity was assumed to grow at a constant rate from 1948 to 1966, and at a different rate from 1967 to the present, to correspond with the productivity slowdown that has been widely observed. Additional "kinks" in f(t) are necessary to help explain the extraordinarily bad productivity performance observed in late 1973 and all of 1974. Three variants of f(t) were used:

(10A) $f(t) = a + bt + cT1$

(10B) $f(t) = a + bt + c(T1) + d(T2)$

(10C) $f(t) = a + bt + c(T1) + d(T3)$

where t = time trend

T1 = 0...0 until 1966:4, then 1,2,3,4...thereafter

T2 = 0...0 until 1973:4, then .25, .5, .75 and 1.0 thereafter

T3 = 0...0 until 1973:3, then 1,2,3,4,5,4,3,2,1, and 0 thereafter.

The "A" variant gives no additional consideration to plummeting productivity in 1974, and just treats it as another set of observations on the cyclical variability of productivity. The "B" variant implies a once-and-for-all downward shift in the trend level of productivity in 1974, possibly due to the shift in the relative price of energy or underestimation of real output in an inflationary environment. The "C" variant explains the lower productivity in 1974 as an extraordinary cyclical movement that disappears by the end of 1975.

Equations (6), (9), and (10 A-C) can be combined to yield a regression equation for total factor productivity in the private non-residential sector which can then be used for estimating potential GNP. Equation (6) implies:

$$\log\left(\frac{Y_t}{I_t}\right) = \log\left(\frac{Y_t^P}{I_t^P}\right) + (\beta_0-1)\log\left(\frac{I_t}{I_t^P}\right) + \beta_1\log\left(\frac{I_{t-1}}{I_{t-1}^P}\right)$$

Substituting in (9) and (10 A-C) yields:

$$\text{(11A)}\quad \log\left(\frac{Y_t}{I_t}\right) = a + bt + cT1 + (\beta_0-1)\log\left(\frac{I_t}{I_t^P}\right) + \beta_1\log\left(\frac{I_{t-1}}{I_{t-1}^P}\right) + u_t$$

$$\text{(11B)}\quad \log\left(\frac{Y_t}{I_t}\right) = a + bt + cT1 + dT2 + (\beta_0-1)\log\left(\frac{I_t}{I_t^P}\right) + \beta_1\log\left(\frac{I_{t-1}}{I_{t-1}^P}\right) + u_t$$

$$\text{(11C)}\quad \log\left(\frac{Y_t}{I_t}\right) = a + bt + cT1 + eT3 + (\beta_0-1)\log\left(\frac{I_t}{I_t^P}\right) + \beta_1\log\left(\frac{I_{t-1}}{I_{t-1}^P}\right) + u_t\,.$$

The regression equations derived from the alternative specification (8) along with equations (9) and (10 A-C) are:

$$\text{(12A)}\quad \log\left(\frac{Y_t}{I_t}\right) \simeq (\alpha_0+\alpha_1)a + (\alpha_0+\alpha_1)bt + (\alpha_0+\alpha_1)cT1 - (\alpha_0-1)\log\left(\frac{Y_t}{I_t^P}\right) - \alpha_1\log\left(\frac{Y_{t-1}}{I_{t-1}^P}\right) + u_t\,.$$

$$(12B)\quad \log\left(\frac{Y_t}{I_t}\right) \simeq (\alpha_0+\alpha_1)\, a + (\alpha_0+\alpha_1)\, bt + (\alpha_0+\alpha_1)\, cT1 + (\alpha_0+\alpha_1)\, dT2 - (\alpha_0-1)\log\left(\frac{Y_t}{I_t^P}\right) - \alpha_1 \log\left(\frac{Y_{t-1}}{I_{t-1}^P}\right) + u_t \,.$$

$$(12C)\quad \log\left(\frac{Y_t}{I_t}\right) \simeq (\alpha_0+\alpha_1)\, a + (\alpha_0+\alpha_1)\, bt + (\alpha_0+\alpha_1)\, cT1 + (\alpha_0+\alpha_1)\, cT3 - (\alpha_0-1)\log\left(\frac{Y_t}{I_t^P}\right) - \alpha_1 \log\left(\frac{Y_{t-1}}{I_{t-1}^P}\right) + u_t \,.$$

It should be noted that the algebraic manipulations required to derive (12) from (8) and (10) imply that the disturbances in (12) will exhibit second-order serial correlation. Thus it was not surprising when second-order serial correlation was found in the estimation of (12) (and handled by a second-order generalization of the Cochrane-Orcutt two stage procedure).

Estimates of the parameters in equations (11 A-C) and (12 A-C) obtained by the Cochrane-Orcutt two-stage procedure are given in Table 5 below. Standard errors are not given for the parameters of f(t) in the estimates of equation(12), since these are obtained by dividing least squares coefficients, implying that they have infinite variance. It is reasonable to assume that equations 11A-C give more reliable estimates, for two reasons. First, the division problem allows estimation errors for α_0 and α_1 in equation (12) to contaminate the growth parameters a, b, and c. Second, the longer lag specification (equation (7)) seems more appropriate than the short 1-period lag in equation (8).

Table 5

Parameter Estimates and Implied Potential GNP for Equations (11A-C) and (12A-C):
Long-Run Growth and Cyclical Variation in Total Factor Productivity
(quarterly data; estimation interval 1948:3 or 4 to 1977:2)

Equation	a	b	c	d	e	(β_0-1)	β_1	$(1-\alpha_0)$	α_1	ρ_1	ρ_2	d-w	$\bar{R}^2$	1955 Potential GNP (billions of 1972 dollars)	1977 Potential GNP (billions of 1972 dollars)
11A	-3.70	.00456	-.00155			.878	-.422			.78		1.70	.997	656.1	1392.4
	(.0095)	(.00017)	(.00038)			(.114)	(.115)								
11B	-3.70	.00443	-.00058	-.042		.822	-.414			.76		1.80	.997	653.7	1378.1
	(.0083)	(.00016)	(.00042)	(.011)		(.111)	(.110)								
11C	-3.70	.00455	-.00139		-.00659	.806	-.352			.79		1.86	.997	655.9	1399.4
	(.0096)	(.00018)	(.00039)		(.0022)	(.112)	(.113)								
12A	-3.69	.00442	-.00099					.656	-.148	1.02	-.34	1.62	.9998	658.8	1413.8
								(.022)	(.022)						
12B	-3.69	.00436	-.00044	-.028				.644	-.163	.97	-.32	1.59	.9998	657.7	1402.6
								(.023)	(.022)						
12C	-3.69	.00441	-.00084		-.00523			.649	-.144	1.08	-.39	1.80	.9998	658.6	1420.4
								(.022)	(.021)						

(Standard errors in parentheses.)

It is difficult to discriminate between the two hypotheses about the 1973-74 "productivity disaster" implicit in the B and C variants of the equations. If the B variant is the correct specification, and the level of productivity shifted downwards in 1974, high inflation rates could be the cause. If such high inflation rates caused price increases to be overestimated, real output has been underestimated, and the productivity loss exaggerated. Some evidence for this view can be found in the Federal Reserve Board Industrial Production Index, which fell less than real GNP over the 1973-75 period. One also suspects the rapid rise in the relative price of energy, although the mechanism for loss in productivity due to the high price of oil is not obvious. In a theoretical model with homogeneous capital, even if the elasticity of substitution were zero, potential GNP measured in 1972 dollars would not fall at all. A Cobb-Douglas formulation generates implausible reductions in energy usage of 40 to 50%. A vintage model for capital could explain the drop only if U.S. capital is more energy intensive than foreign capital. In this case, production using the most energy-intensive capital in the U.S. might not cover variable costs at world output prices.

The other view, consistent with the "C" specification, is that the cyclical movement in productivity was just much stronger in the 1973-75 recession than in previous downturns. Probably the truth lies somewhere in between; a once-and-for-all drop in total factor productivity of about 2% combined with some extra cyclical loss may be close to correct.

The estimates of potential GNP shown in Table 5 are derived by eliminating the cyclical components in each equation and setting labor and capital inputs to their potential values. This yields a potential for private nonresidential GNP, which then is added to the non-cyclical components (compensation of government employees, imputation to the residential capital stock, and income from investment abroad) to obtain potential GNP. The B variant shows the lowest potential for 1977, reflecting the pessimistic assumption that the drop in productivity in 1974 not explainable by normal cyclical factors was permanent. The equation (12) estimates are higher than those from equation (11); this difference may be caused by incorrect specification of the lag between changes in output and input gaps in equation (12). For example, the long-run elasticity of the input gap with respect to the output gap is $1/(\beta_0 + \beta_1) = .716$ in equation (11B), while the same elasticity is $(\alpha_0 + \alpha_1) = .562$ in equation (12B). By allowing the lag to be longer in (11), the sum of the coefficients is larger; the larger long-run elasticity implies a smaller output gap for a given input differential.

Estimates Using Only Labor Input

Discussions of potential output are usually based on labor input only, largely because the measurement of the capital stock is based on a number of arbitrary (but necessary) assumptions, and because the weight of capital in total input is the subject of some controversy. It is instructive, then, to investigate the effect of the capital stock estimates on the calculation of potential output by performing the analysis using labor input only. All the same equations ((11A-C) and

(12A-C)) may be estimated by replacing I_t, the combination labor and capital input, with L_t, the labor input component only. The basic equations are then

$$(6')\quad \frac{Y_t}{Y_t^P} = \left(\frac{L_t}{L_t^P}\right)^{\beta_0} \left(\frac{L_{t-1}}{L_{t-1}^P}\right)^{\beta_1} ,$$

$$(8')\quad \frac{L_t}{L_t^P} = \left(\frac{Y_t}{Y_t^P}\right)^{\alpha_0} \left(\frac{Y_{t-1}}{Y_{t-1}^P}\right)^{\alpha_1} ,$$

and

$$(9')\quad \log\left(\frac{Y_t^P}{L_t^P}\right) = f(t) + u_t .$$

The analysis is exactly the same, but the basic productivity concept is labor productivity instead of total factor productivity. If the capital input measure is sufficiently poor, ignoring capital will produce better estimates. The results of the "labor input only" regressions are given in Table 6.

The results are virtually identical; estimated potential GNP is about 1% lower in 1955 and about 1% higher in 1977. The difference is primarily due to somewhat higher capital utilization rate relative to the unemployment rate in the mid-1970s, compared to 20 years earlier.

The elasticity of the output gap with respect to the labor input gap is higher than the elasticity of the output gap with respect to the weighted gap for labor and capital. $1/(\beta_0 + \beta_1) = .569$ for equation (11B') while $(\alpha_0 + \alpha_1) = .400$ for equation (12B'). This is not surprising, for capital utilization should adjust more rapidly to output

Table 6

Parameter Estimates and Implied Potential GNP for Equations (11A-C') and (12A-C'):
Long-Run Growth and Cyclical Variation in Labor Productivity
(quarterly data: estimation interval 1948:3 to 1977:2)

Equation	a	b	c	d	e	(β_0-1)	β_1	$(1-\alpha_0)$	α_1	ρ_1	d-w	$\bar{R}^2$	1955 Potential (billions of 1972 dollars)	1977 Potential (billions of 1972 dollars)
11A'	-3.11	.00683	-.00179			1.79	-.98			.77	1.75	.998	650.2	1405.5
	(.011)	(.00020)	(.00044)			(.20)	(.20)							
11B'	-3.11	.00671	-.00081	-.045		1.67	-.99			.77	1.86	.998	648.0	1389.6
	(.010)	(.00020)	(.00052)	(.014)		(.20)	(.20)							
11C'	-3.11	.00682	-.00162		-.00690	1.67	-.86			.78	1.87	.998	650.0	1413.1
	(.011)	(.00020)	(.00045)		(.00265)	(.20)	(.20)							
12A'	-3.10	.00663	-.00117					.784	-.190	.85	1.15	.9998	651.8	1421.9
								(.022)	(.021)					
12B'	-3.10	.00654	-.00053	-.029				.773	-.197	.86	1.19	.9998	650.2	1410.1
								(.022)	(.020)					
12C'	-3.10	.00663	-.00109		-.00679			.771	-.188	.86	1.27	.9998	651.8	1426.2
								(.021)	(.020)					

(Standard errors in parentheses)

than labor utilization. It is also not surprising that the sum of the coefficients $\alpha_0 + \alpha_1$ is very close to the sum reported in "Okun's Law" equations, given that (12') is essentially Okun's Law, as explained earlier. Unlike the total factor productivity estimates, second order serial correlation was not significant in (12A' - 12C'), implying that some other form of specification error is responsible for the low Durbin-Watson statistic after the first-order serial correlation correction.

The range of the 12 estimates of potential GNP derived from the regression equations are given in Table 7 and shown pictorially in Figure 1. Projections of the labor force, capital stock and the components of noncyclical output given in Tables A-1, A-2, and A-6 were used to obtain potential GNP projections to 1980. The large increase in the range of potential since 1973 reflects the uncertainty generated by the precipitous productivity decline in 1974. By 1980, the range of estimates is almost 4% of potential GNP, a figure that does not overestimate our ignorance about the level of output in 1980, when unemployment and capacity utilization may be nearer their benchmark levels.

Most of the productivity decline since the late 1960s cannot be explained by the changing age-sex composition of the labor force, the changing industrial composition of labor-hours, or changes in the rate of growth of the capital/labor ratio.[17/] Instead, the slowdown must be allocated to a residual category, or "technical progress." Since reasons for apparent changes in the trend rate of productivity growth are not well understood, it may be the case that the trend productivity

Table 7

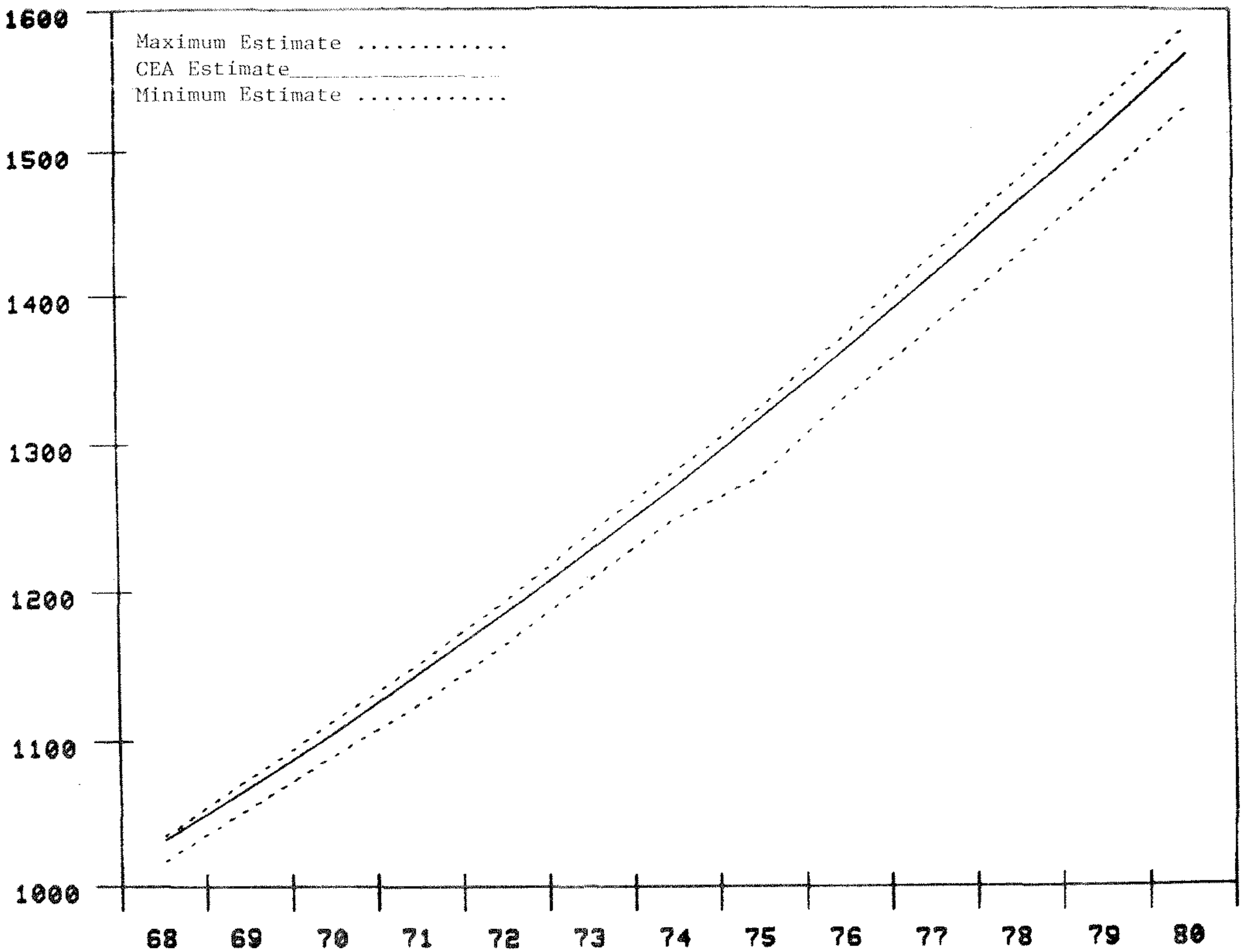
Estimates of Potential GNP
(billions of 1972 dollars)

Year	Minimum Estimate	Maximum Estimate	1977 CEA Estimate
1948	494.5	501.8	492.8*
	517.1	524.6	514.4*
1950	535.7	543.6	537.0*
	560.0	571.0	560.5*
	580.8	593.7	584.9
	604.0	615.9	608.2
	625.1	636.5	627.7
1955	648.0	658.8	651.4
	676.0	685.7	673.9
	696.0	708.1	697.2
	721.9	732.0	721.3
	743.5	752.9	746.2
1960	772.0	779.6	771.9
	801.0	807.1	798.6
	819.9	828.5	826.4
	848.6	856.5	857.1
	880.8	888.3	890.3
1965	913.9	923.3	925.0
	944.6	957.7	960.8
	981.9	997.2	996.3
	1017.4	1034.1	1031.7
	1053.8	1074.1	1068.3
1970	1090.8	1114.4	1106.2
	1124.9	1152.2	1145.5
	1165.3	1194.2	1186.1
	1208.8	1240.2	1228.2
	1249.2	1282.0	1271.7
1975	1278.6	1324.9	1316.9
	1331.7	1373.7	1363.6
	1378.1	1426.2	1412.0*
	1426.0	1477.7	1462.1*
	1477.1	1530.9	1513.9*
1980	1531.6	1587.5	1567.7*

* Unofficial

Figure 1

Potential GNP: CEA Estimate and Range 1968-1980
(billions of 1972 dollars)



growth rate will be higher from 1977 to 1980 than it was from 1966 to 1973. Even if there was a permanent 2% loss in productivitv in 1974, altered relative prices may generate the incentive for productivity increases that were not particularly profitable at low energy prices. Therefore, cautious optimism either in the form of assuming that the 1974 productivity decline was temporary, or in the assumption that the productivity growth trend will be higher from 1977 to 1980 than it was in 1966-73, generates potential GNP in 1980 of about $1560 billion 1972 dollars.

The estimates for the years 1952-1968 conform very closely to previous estimates of potential output for the U.S. economy. Potential GNP is calculated to be very close to actual GNP ($654.8 billion 1972 dollars) in 1955, and the growth rate of potential is very close to Okun's original estimate of 3.5% per year for 1952-1962.[18/] The growth of potential in 1962-68 is also very close to the 3.75% per year that had previously been estimated by the Council of Economic Advisers.[19/] Since 1968, however, the growth in potential output has been much lower than was previously estimated. Potential output growth for 1968-75 is estimated here at about 3.5% per year instead of 4.0% for that period estimated by the Council in 1976.[20/]

Although part of the difference between the previous 4% growth rate and the new CEA 3.5% rate can be explained by the increase in the unemployment benchmark from 4 percent to 4.9% in 1976, by far the largest part of the decrease is due to slow productivity growth. Calculations of the trend in total factor productivity using 4% unemployment as a benchmark indicate that estimated potential GNP would be .3 to 1.1 percent higher with this standard, depending on how the reduced unemployment is distributed among demographic groups.

Unemployment and Real GNP Change: Checking the Results

As a rough check on the potential GNP estimate of 1332-1374 billion 1972 dollars for 1976, the relationship between changes in the overall unemployment rate and changes in real GNP was estimated using equations 13A and 13B.

$$\text{(13A)} \quad \Delta U_t = \underset{(.04)}{.38} - \underset{(.02)}{.24^*}\,\Delta\%GNP_t - \underset{(.02)}{.18^*}\,\Delta\%GNP_{t-1}$$

$\bar{R}^2$ = .77 d-w = 1.89 data: quarterly 1953:2-1976:4

$$\text{(13B)} \quad \Delta U_t = \underset{(.04)}{.45} - \underset{(.02)}{.25^*}\,\Delta\%GNP_t - \underset{(.01)}{.10^*}\,\Delta\%GNP_{t-1}$$

$$- \underset{(.01)}{.08^*}\,\Delta\%GNP_{t-2} - \underset{(.005)}{.05^*}\,\Delta\%GNP_{t-3} - \underset{(.003)}{.03^*}\,\Delta\%GNP_{t-4}$$

(last four regression coefficients constrained to lie on a straight line)

$\bar{R}^2$ = .75 d-w=1.89 data: quarterly 1953:2-1976:4

$\Delta U_t = U_t - U_{t-1}$ = percentage point change in the overall unemployment rate U.

$\Delta\%GNP_t = 100^*(GNP_t - GNP_{t-1})/GNP_{t-1}$, = percentage change in Gross National Product measured at 1972 prices.

Equation 13A implies that a one percentage point reduction in the overall unemployment rate will be associated with a 2.4 percent increase in real GNP in the long run, while equation 13B implies an eventual 2.0 percent increase. A 2.8 percentage point decrease in the unemployment rate in 1976 from the realized 7.7% to the 4.9% CEA benchmark, would therefore increase real GNP 5.6 to 6.7%. Since GNP at 1972 prices was $1264.7 billion in 1976, these increases imply a potential output of 1336 to 1350 billion 1972 dollars. These figures are below the middle of the potential GNP range for 1976.

It should be noted that the result of 2.5 or less for an estimate of $\% \Delta$ GNP/Δ U is lower than the 3.0 or greater used by some economists. The confusion here probably lies in the distinction between the short-run and long-run responses of unemployment to output. In the short run (one quarter), it takes an additional increase of 4% in real output to reduce unemployment by an additional one percentage point. However, additional unemployment reductions are forthcoming in future quarters, even if there are no additional marginal increases in real output. Since attention is focused on real growth and unemployment during periods of slack economic activity, it is natural to estimate the growth in output that would give an acceptable decline in the unemployment rate. At the beginning of a recovery, this "required real growth" may be very high.

Conclusion

The new CEA estimates of potential output are confirmed by the updated results presented in this paper. The changes generated by an additional year's data are very small, with the biggest adjustment being the increase in the unemployment benchmark from 4.9% to 5.1%. The atypical productivity decline experienced in 1974 has not been reduced in the past year, adding more weight to the argument that 2 to 3 percent was permanently lost from the trend level of productivity.

The CEA potential GNP estimates in the 1977 Economic Report of the President are, if anything, optimistic about the gains in output resulting from a reduced level of unemployment. In the second quarter of 1977, CEA estimated that a reduction in the unemployment rate from the observed 7.0% to 4.9% would have increased real GNP from $1330.7 to $1405.8 billion, or 5.6%. The 1977:2 potential estimates range from 1372.3 to 1419.6 billion, using a slightly higher 5.1% unemployment benchmark. "Okun's Law," with a multiplier of 2.0 to 2.5, yields a range of $1386.6 to $1400.6 billion, using the 4.9% unemployment benchmark. Thus, the results reported here indicate an "output gap" which is generally smaller than the official CEA gap of 5.6%. Estimates of the current output gap which are significantly larger than 5.6% must be based on assumptions about large cyclical variations in the labor force and productivity which are unsupported by the data.

Results on the "potential growth rate" for the economy over the next five years are much less precise. Structural models (as opposed to the empirical trend-fitting equations used in this study) of growth in labor force participation and productivity have not been developed to the point that they can be used to make good conditional predictions. Therefore, any projection of potential output must be an extrapolation of past trends. A growth rate in potential output of 3.5% per year is consistent with the growth rates of the labor force and output per worker which have been observed since the late 1960s. However, high labor force growth, coupled with a return to the pre-1966 trend in total factor productivity, strong capital stock growth and lower relative youth unemployment rates could generate spectacular economic growth over the next five years. Alternatively, sluggish performance in all these areas could result in a very low real growth rate. Erratic behavior of productivity, coupled with recent changes in labor force participation trends and unstable prices make any projection of future growth rates subject to wide variability.

Footnotes

1/ Annual Report of the Council of Economic Advisers, January 1962, p. 49ff.

2/ See Okun (11) for an explanation of the various methodologies used to relate unemployment and real output.

3/ For example: Kuh (8), Thurow and Taylor (20), Black and Russell (1) and Perry (12).

4/ CEA was not alone in its concern about its "old" estimates of potential output. Data Resources voiced its concern over the potential output estimates in early 1976 (Brinner (3)). Publication of the 1977 Economic Report generated additional studies, including Perry (13), and Rasche and Tatom (15).

5/ See the 1977 Economic Report of the President for a non-technical discussion of the issues involved, and Clark (4) for some of the statistical results used in the re-estimation process.

6/ This concept of the private sector is close to what Denison calls the "nonresidential business sector." See Denison, (6), p. 21ff. It is also very close to the Bureau of Labor Statistics' "private business sector."

7/ See Musgrave, (9), and Segel and Rutledge, (17).

8/ See Raddock and Forest, (14).

9/ Data are available by age and sex for May of the years 1973-1976. 1973 was chosen because it is closest to a cyclical peak. Such an adjustment is sometimes called "Perry-weighting" since a similar weighting scheme was used by George Perry in adjusting the unemployment rate: (12).

10/ See, for example, Sclove, (16).

11/ Bureau of Labor Statistics, Employment and Earnings, various issues.

12/ See Stein, (19). Since the parallel surveys in 1966 used for this adjustment are only half the size of the CPS, these ratios are subject to considerable sampling variability.

13/ As mentioned earlier, this result indicates that the unemployment rate for all persons 25-64 could be used as a cyclical indicator in place of the unemployment rate for men 25-64. Observations of the adult womens' unemployment rate relative to that of adult men shows a .5 point increase in the differential between them from 1962-1966, a .7 point increase in 1967 (as predicted by the BLS partial samples) and then a .6 point decrease from 1967 to 1968. This strange behavior of the women's unemployment rate influenced the decision to use the rate for adult men, although results using either rate are virtually identical.

14/ See G.E.P. Box and G.M. Jenkins, (2), p. 67ff, for a discussion of the conditions under which a moving average process such as (6) can be converted to a one-sided autoregressive scheme.

15/ This lagged response is sometimes called "short-term increasing returns to labor." See Sims, (18).

16/ One possibility is that capital input response is instantaneous, while labor input response is lagged. This implies a cyclical adjustment that treats labor and capital inputs differently. Experiments with such a specification yielded results insignificantly different than those reported below.

17/ See Norsworthy and Fulco (7) for a discussion of the reasons for the productivity slowdown. Embodied technical progress and investment in research and development may have contributed to the slowdown, but these factors were not analyzed.

18/ Okun, (8).

19/ Business Conditions Digest, August 1976, p. 95.

20/ Ibid.

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3/ Brinner, R.E., "The Growth of Potential GNP," The Data Resources U.S. Long-Term Bulletin, Winter 1976, p. 91-110.

4/ Clark, P.K., "A New Estimate of Potential GNP," in U.S. Congress, Joint Economic Committee, Hearings on the Economic Report of the President, January 19, 1977.

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18/ Sims, C.A., "Output and Labor Input in Manufacturing," Brookings Papers on Economic Activity, (3:1974).

19/ Stein, R.L., "New Definitions for Employment and Unemployment," Monthly Labor Review, February 1967.

20/ Thurow, L.C., and L.D. Taylor, "The Interaction Between Actual and Potential Rates of Growth," Review of Economics and Statistics, November 1966, p. 351-60.

21/ U.S. Department of Commerce, Business Conditions Digest, August 1976.

Table A-1

Fixed Nonresidential Capital Stock at 1972 Prices
Excluding Pollution Abatement Capital
(billions of 1972 dollars)

1948	632.8		
	658.0		
1950	681.1		
	707.5	1966	1164.2
	734.2		1219.3
	761.1		1273.3
	787.9		1331.1
1955	815.4	1970	1387.6
	845.7		1437.2
	876.3		1486.1
	902.2		1541.7
	925.0		1600.6
1960	950.5	1975	1649.0
	976.4		1687.1
	1003.6		1729.9
	1033.5		1783.5
	1067.2		1845.6
1965	1110.4	1980	1913.2

Note: Figures are average values of capital stock during the given year.

Table A-2

Potential Civilian Labor Force 1948-1980
(millions of persons)

1948	60.6		
	61.5		
1950	62.4	1966	75.6
	62.0		77.2
	62.1		78.6
	62.9		80.5
	63.8	1970	82.7
1955	65.0		84.3
	66.5		86.7
	67.0		88.7
	68.0		91.1
	68.6	1975	93.3
1960	69.8		95.9
	70.8		98.0
	70.8		99.7
	72.0		101.4
	73.2	1980	103.3
1965	74.4		

Table A-3

Private Employment, 1948-1975
(millions of persons)

1948	53.1	1960	57.8
	52.3		57.6
1950	53.1		58.0
	53.9		58.7
	53.8		60.0
	54.7	1965	61.5
	53.5		62.6
1955	55.3		63.2
	56.9		64.3
	56.9		65.9
	55.6	1970	66.2
	56.9		66.3
			68.4
			70.8
			71.9
		1975	70.3
		1976	72.5

Table A-4

Estimated Capacity Utilization Rate
for the Private Sector, 1948-1976[a]
(percent)

1948	85.0	1961	82.4
	80.8		84.5
1950	85.2		85.5
	86.7		86.6
	86.4	1965	88.5
	88.4		89.3
	83.8		87.2
1955	87.3		87.3
	86.8		86.9
	85.6	1970	83.4
	81.3		82.8
	84.6		85.3
1960	83.8		87.5
			85.8
		1975	80.5
		1976	83.8

a Annual average rate. Quarterly series (R_t) is derived from the FRB manufacturing utilization rate (F_t) (see Raddock and Forest (10)) according to the following formula:

$$R_t = 1/2\ (87.5 + F_t)$$

Table A-5

Full Employment Unemployment Benchmark
Equivalent to 4.0 Percent Unemployment in 1955
(percent)

1948	4.4		
	4.3		
1950	4.3		
	4.2	1966	4.6
	4.1		4.5
	4.0		4.5
	4.0		4.6
1955	4.0	1970	4.7
	4.1		4.7
	4.1		4.9
	4.1		5.0
	4.1		5.0
1960	4.2	1975	5.1
	4.2		5.1
	4.2		5.1
	4.3		5.2
	4.3		5.2
1965	4.5	1980	5.2

Note: Unemployment rates are computed relative to the sampling procedure actually used in a given time period. The CPS survey change in 1967 causes the shift in the benchmark unemployment rate from 1966 to 1967.

Table A-6

Projections of Noncyclical GNP Components 1976-1980
(billions of 1972 dollars)

Year	Compensation of Federal Employees	Compensation of State and Local Government Employees
1976[a]	48.4	97.3
1977	48.6	98.7
1978	48.6	101.9
1979	48.7	105.2
1980	48.7	108.7

	Gross Ouput Attributed to Residential Housing Stock	Gross Ouput Originating in Rest of World (GNP-GDP)
1976[a]	111.6	6.7
1977	114.8	8.0
1978	118.4	9.2
1979	122.2	10.3
1980	126.2	11.3

[a] 1976 figures are actual, included for comparison.

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.

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

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

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

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:

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

$R^2 = .99$ 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		

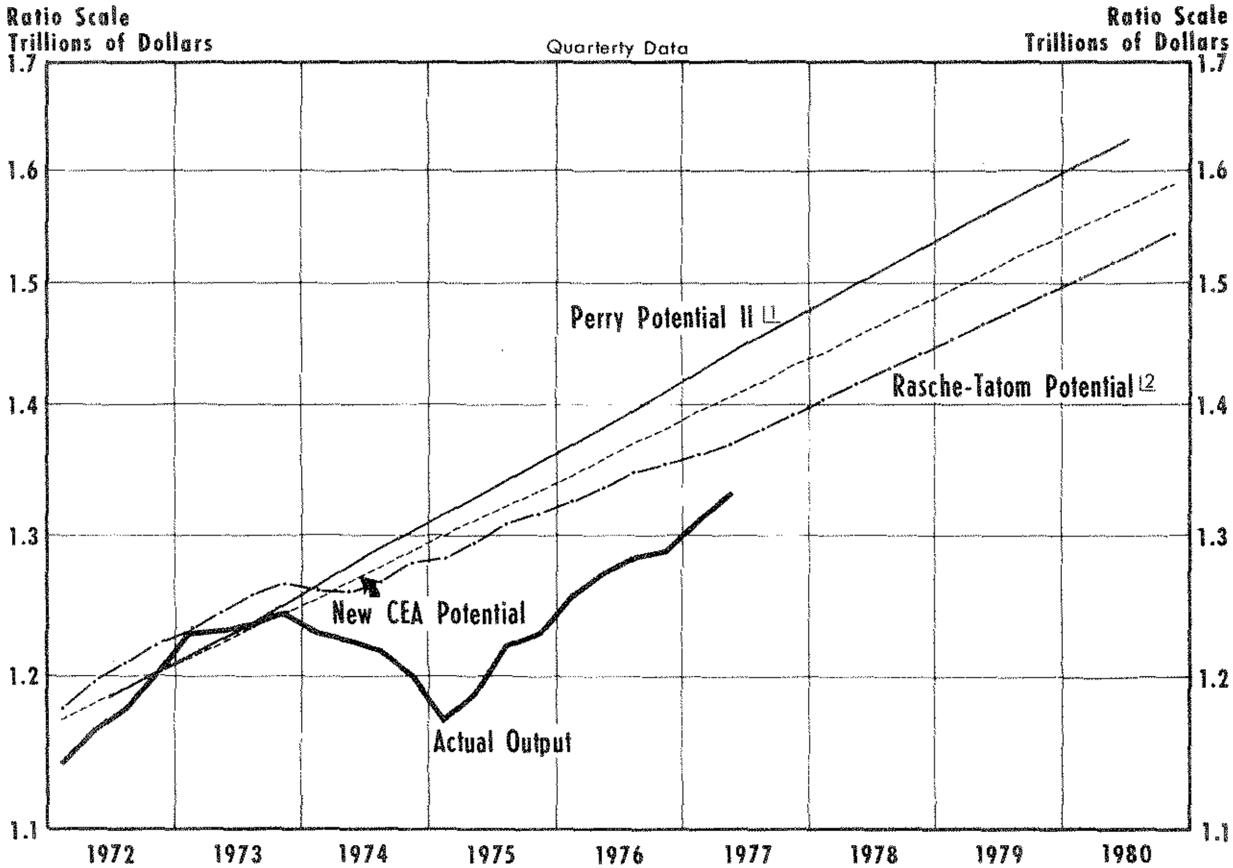
TABLE 2

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]

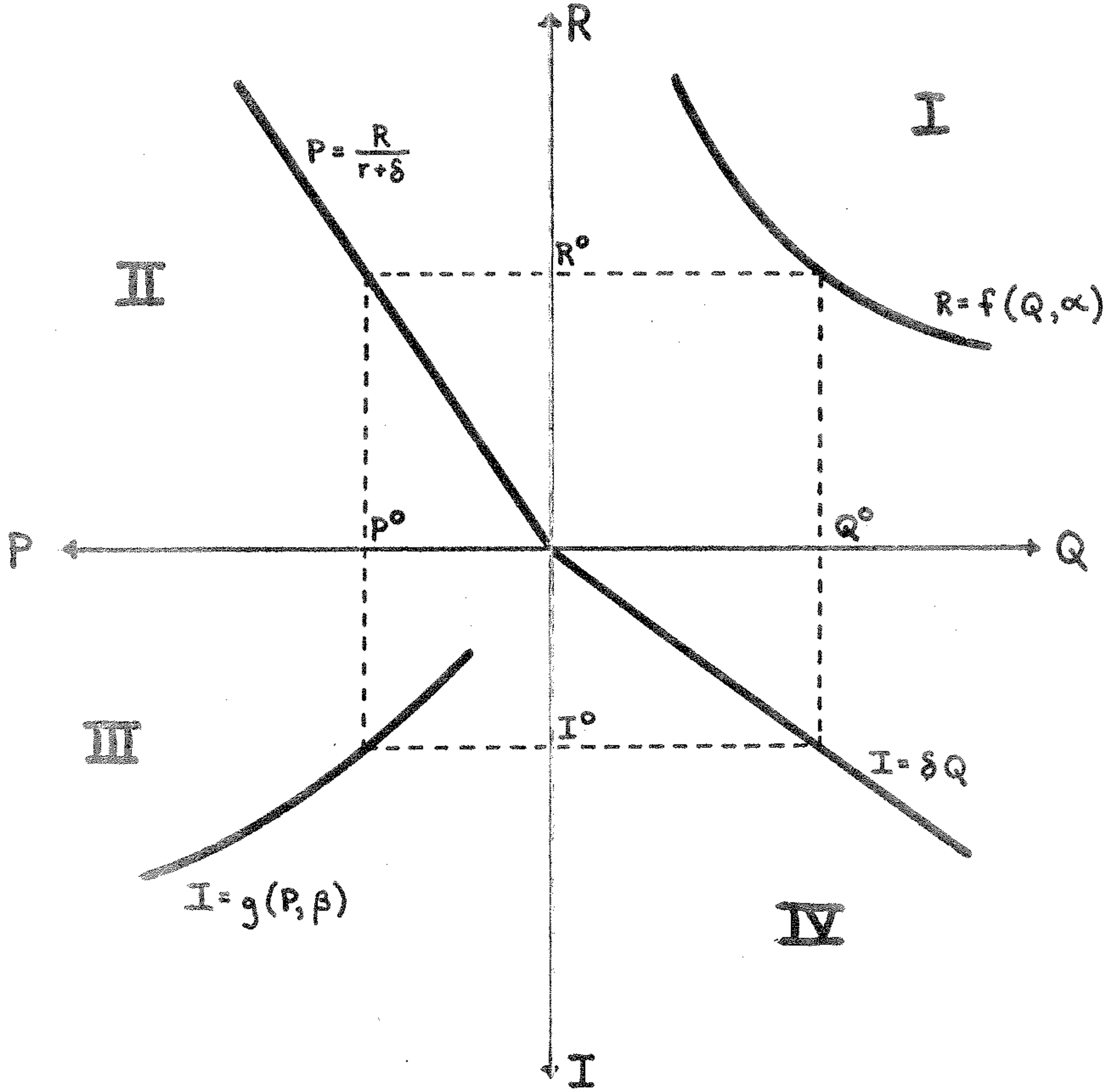
In the case of capital resources, the result is much clearer. The reduction in the rental price of existing capital due to a leftward shift in the demand for the stock or flow of services of capital also shifts the demand for new capital goods. Other things equal, investment tends to fall, as does the 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



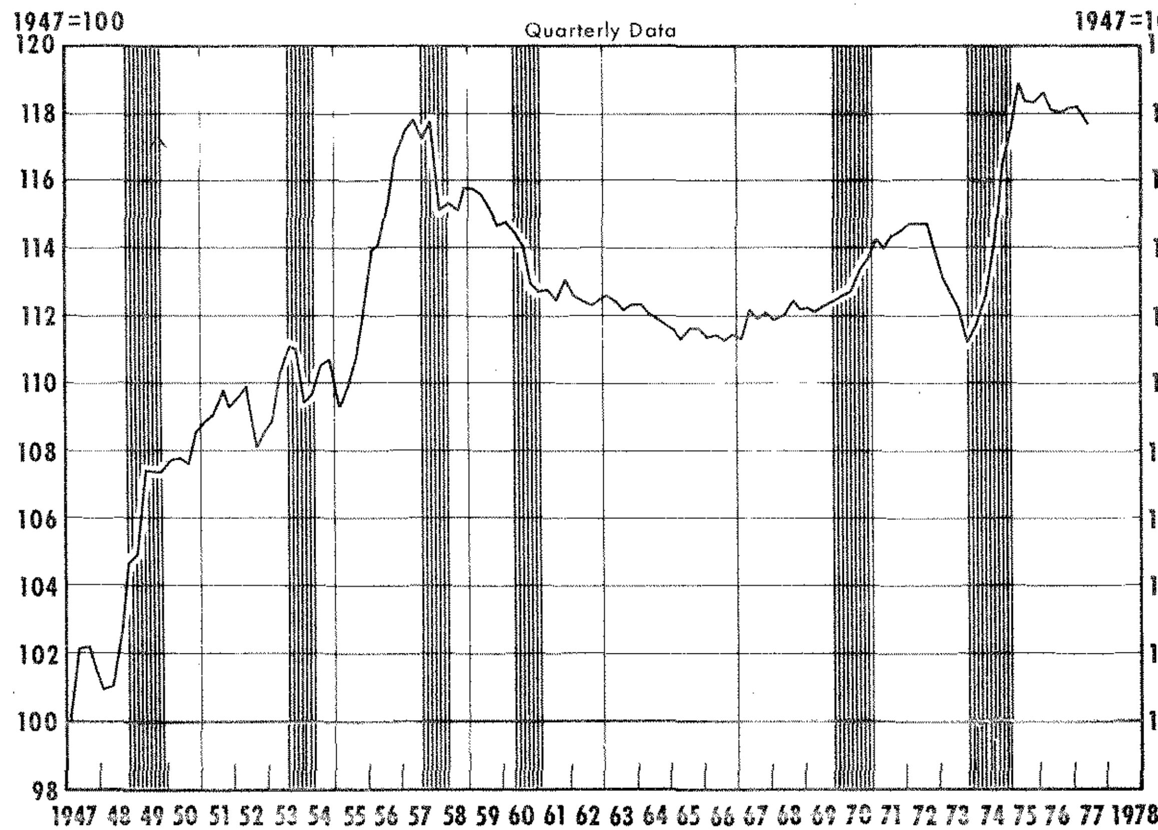
capital, a lower stock and rate of replacement of capital and a higher rental price. Finally, combining both shifts yields a smaller capital stock in the steady state -- achieved through a temporary decline in the net investment rate. Whether the steady state price of capital and rental price of its 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:

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

$$(-1.68) \quad (5.18)$$

$R^2 = .23$ 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.

The Growth Rate of the Net Stock of Plant and Equipment -- 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.

WILL BOTTLENECKS SLOW THE EXPANSION?

William D. Nordhaus

The topic of this conference is indeed an important one. Although currently the United States economy suffers from considerable excess capacity, both in labor and in product markets, we hope that this condition will not last forever. What I would like to discuss this afternoon is the state of utilization and the extent of imbalance in different markets, and possible strategies for avoiding bottlenecks during this recovery.

The Legacy of the Recession

Starting roughly five years ago the world economy was struck by a series of shocks which culminated in the worst inflation, and thereafter the worst recession, of the post-war era. A simultaneous boom in all the industrial countries led to severe capacity shortages in major industries, especially materials industries. Following the 1973 boom, and the food and oil inflation that succeeded it, virtually every major industrial country suffered a severe recession.

The imbalances that developed in the boom of 1972-73, together with the devastating effects of the oil and grain shocks were enough to cause a downturn. But the fiscal and monetary authorities added their own restrictive influences. Thus, examining the OECD area:

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- The narrowly defined money supply (M-1) decelerated from an annual growth rate of over 12 percent at the beginning of 1973 to below 7 percent at the end of 1974.

- Since prices in the OECD were rising at approximately 13 percent annually, this means that the real money supply was falling at almost 6 percent per annum by the end of 1974.

- As a result of the monetary stringency, short-term rates rose from around 6 percent at the beginning of 1973 to 11 percent in the second half of 1974 and long-term rates rose about a point and a half.

- Fiscal policy turned sharply toward contraction after the 1973 boom. Real government expenditures from 1973 to 1974 rose only 1 percent in the United States and United Kingdom, 4 percent in Germany, and fell in Japan.

The effect of these forces is by now well known. One particularly disturbing legacy of the recession has been its effect on investment and thereby the level of capacity in the United States and abroad. Although measurement of capacity is quite difficult, the estimates show a significant decline in the growth of capacity in manufacturing industries over the last ten years. From 1948 to 1968, growth of capacity in manufacturing averaged 4.5 percent per year. From 1968 to 1973, the growth rate dropped to 4 percent per year. But in the period from 1973 to 1976, capacity grew at only 3 percent per annum. This means that over the last three years, the growth of capacity has not matched what we would need to keep up with potential output -- even with the most pessimistic of the estimates of potential that we have heard today.

Examining the latest data, we see that the growth in capacity leaves much to be desired, as is shown in Table 1.

TABLE 1.

Rate of Growth in Capacity 1976:2 to 1977:2

Manufacturing	2.8%
Primary processing	3.2%
Advanced processing	2.5%
Materials	
Basic metal	1.4%
Textile	2.1%
Paper	3.0%
Chemical	4.8%
Energy	2.3%

For all of manufacturing the growth rate of the last year has been less than 3 percent, with basic metal materials showing the smallest increase and chemicals showing the most rapid.

It is clear that the recent slowdown in the growth of capacity must be reversed. We cannot hope to sustain a noninflationary expansion over the next three or four years, reaching high employment, without a major acceleration in the growth of capacity.

The Current Imbalance in Labor and Product Markets

Given the slow growth of capacity during the current recession, it is inevitable that an imbalance between labor markets and capital or product markets arises. To make more clear what the nature of this imbalance is, let us consider capacity output as it is distinguished from potential output:

- o Potential output is conventionally defined as the level of output that would be produced at a reference unemployment rate, or weighted unemployment rate. In computing potential output, it has been conventional (up until recently) to assume that there are no capacity constraints. This can be rationalized by assuming that, through the accelerator principle on investment, the level of capacity adjusts with a distributed lag to the level of demand. If this is the case, and if labor is inelastically supplied, the ultimate constraint on output is labor input rather than capital.

o Capacity output can be viewed as the level of output which can be produced with the current capital stock. Clearly, the definition of capacity differs across industries, both because of flexibility of productive techniques in some industries and the possibility of shift work in others. Nevertheless, expecially in continuous processing industries, capacity has a definite meaning.

It is useful to compare the state of utilization of labor and product markets by looking at what will be called the full employment capacity utilization. To calculate the full employment capacity utilization index, we need to know the relation between capacity utilization and the level of unemployment. Then, using an "Okun's law for capacity," we can estimate what the level of capacity utilization would be if the unemployment rate were at "full employment."[1/] We have taken the "full employment" definition to be the weighted-average unemployment rate used in the CEA potential output series, this corresponding approximately to a 5 percent rate today.

We have investigated the relationship between these two series over the last twenty years, using a number of alternative techniques. Figure 1 shows the result of one of these experiments. According to this graph the period from the mid-1950s until the mid-1960s showed a gradual upward creep in the full employment capacity utilization index. Then starting in 1965 and lasting until approximately 1970, there was a

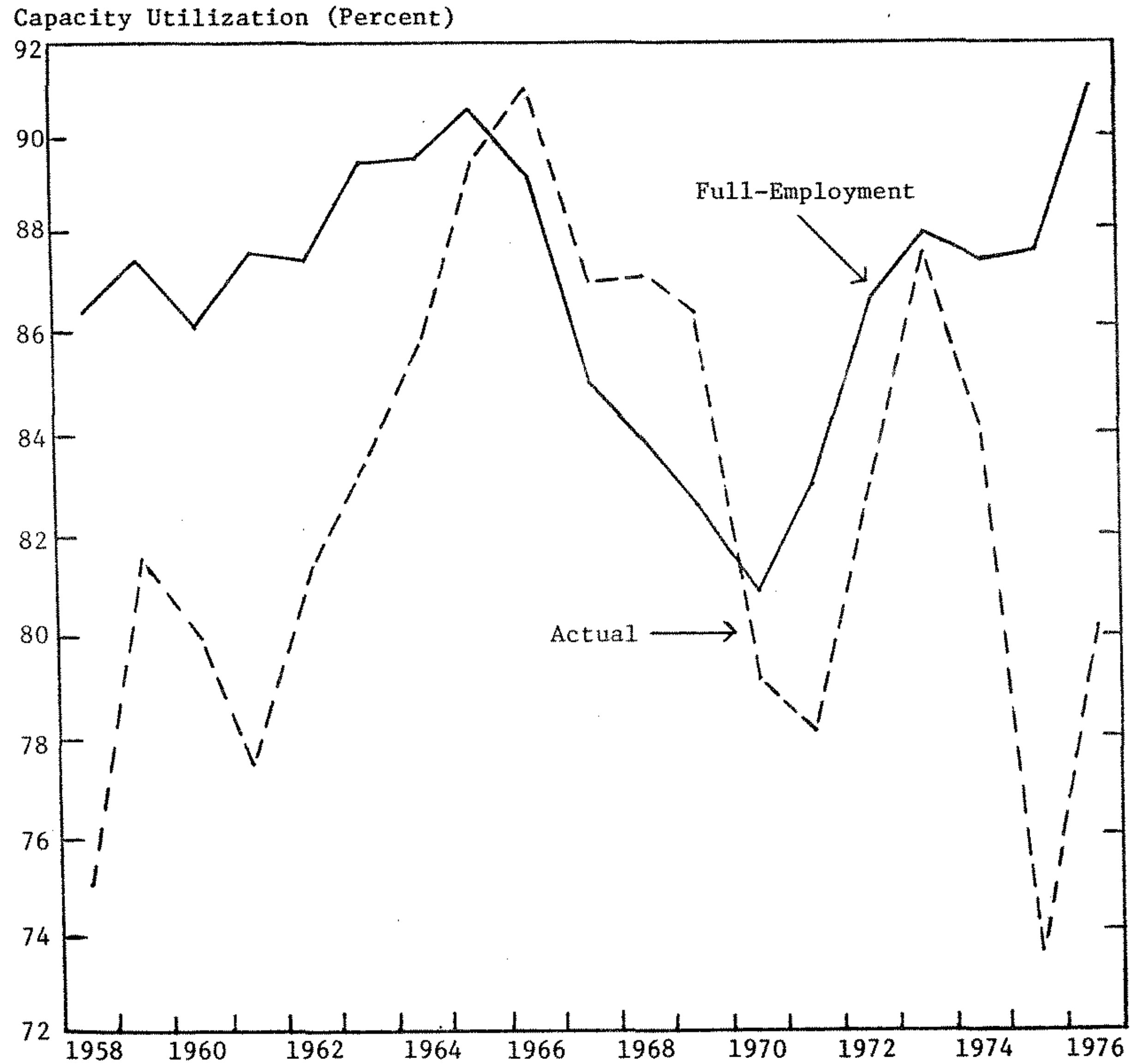

Figure 1. Actual and Full-Employment Capacity Utilization (Federal Reserve Index)

dramatic decrease in this, reflecting the potency of the investment boom of the 1960s. Starting in 1970, however, there was a definite and sharp upward rise in the full employment capacity utilization index. Over the last six years full employment capacity utilization has risen from approximately 81 percent to the current level of 91 percent.

The full employment capacity utilization index is an indication of how tight product markets in manufacturing would be, today, if we were at full employment (and potential output as defined above). These can be compared with historical experience. The capacity utilization rates of the Federal Reserve Board, which we are using here, averaged about 83 percent for manufacturing for the period 1955 through 1975, and about 86 percent for industrial materials from 1967 through 1975. The highest level of the capacity utilization index for manufacturing which has been experienced for an entire year since 1948 was 91 percent in 1966. The most recent period of high utilization was in 1973. In that year capacity utilization in manufacturing averaged 88 percent, while primary processing industries had a utilization rate of 92 percent.

What are the implications of this apparent rise in the full employment capacity utilization index? The obvious point is that we cannot expect to have high levels of employment without one of the three following possibilities: 1) a significant investment boom; 2) a major change in the composition of our output away from manufacturing and materials; or 3) operating rates in manufacturing and materials which are well above those which are normally experienced.

Or put differently, it is clear that if the capacity and utilization data of the Federal Reserve Board are relatively accurate, then there is currently insufficient capacity to sustain an immediate gallop to full employment.

Returning to our earlier discussion, we noted that one of the most significant bequests of the recent recession was insufficient investment. Before the recession got underway, our index was considerably lower: thus in 1973 the full employment capacity utilization index was 88 percent, 3 percent lower than it stands today. The investment slump and associated problems of the last three years have apparently raised our full employment capacity utilization index three full points.

The Break-even Capacity Utilization

Why has the growth of capacity not kept up with the growth of potential output? This is the other side of the question, "why has investment lagged so badly during the current recession and recovery."

CEA has studied the reasons behind the investment lag, using a number of economic theories of investment. Although different models give different answers, the basic reason -- and one that can hardly be surprising -- is that the demand for future capacity is performing poorly because the level of utilization of today's capacity has been so low. There are other factors as well -- environmental regulations certainly have raised the cost of additional capacity in many heavy industries (steel, utilities, and chemicals being among the most heavily affected). In addition, the depressed state of the stock market hardly is conducive to new ventures, although -- to be sure -- stock market prices (and in particular the ratio of market value to replacement costs, Q) have reflected quite closely levels of utilization of capacity over recent years. Finally, there has been a clear shift in the composition of investment away from long-lived investments -- especially structures -- and toward equipment.

Nonwithstanding the caveats, however, it is probably the case that the major reason for the depressed state of investment is the low levels of capacity utilization the economy has experienced over the last three years. We know that very low levels of utilization -- operating through the accelerator mechanism -- lead to a slowdown in investment and in the growth of capacity. If capacity is below some "break-even" point, and investment therefore insufficient to keep capacity growing rapidly enough, we may actually be in the situation where capacity is growing less rapidly than potential output. The full employment capacity utilization rate would therefore rise and the imbalance between labor and product market would widen. It is ironic that in pursuing an anti-inflation policy which keeps the level of slack in the economy very high, we have created a situation in which future bottlenecks become more likely.

As a way of illustrating the relation between the growth of capacity and capacity utilization, we have run a standard investment equation. The equation relates the level of investment to the rental cost of capital and non-linearly to the level of capacity utilization.

Then by taking into account the historical relation between investment and capacity growth, we can ask whether the level of capacity utilization has been sufficiently high to assure that capacity growth is as rapid as potential output.

Figure 2 shows a graphic representation of the relation between capacity utilization and capacity-potential difference. In making this relationship, we have assumed that the real cost of capital (in terms of percent per annum) was at its post-war average, so that there was no extraordinary push or pull from monetary or fiscal incentives. The figure shows quite clearly that the difference between the growth of measured capacity and potential output is positively and non-linearly related to the appropriately lagged rate of capacity utilization.

One can calculate from such a relationship, assuming no change in the historical level of capacity utilization at which the capital stock has grown at the same rate as potential output, the break-even utilization rate. This presumes, as has been the case recently, that -- if imbalances are not to appear -- potential output will grow approximately 1.2 percent per annum faster than the capital stock.

According to these relationships, the break-even capacity utilization point is around 84 percent. That is to say, when capacity utilization is 84 percent, and assuming the relationship is the same as in the historical period, capacity output will be growing as rapidly as potential output. On the other hand, if utilization is lower than this -- say the 74 percent in 1975 or 80 percent in 1976 --

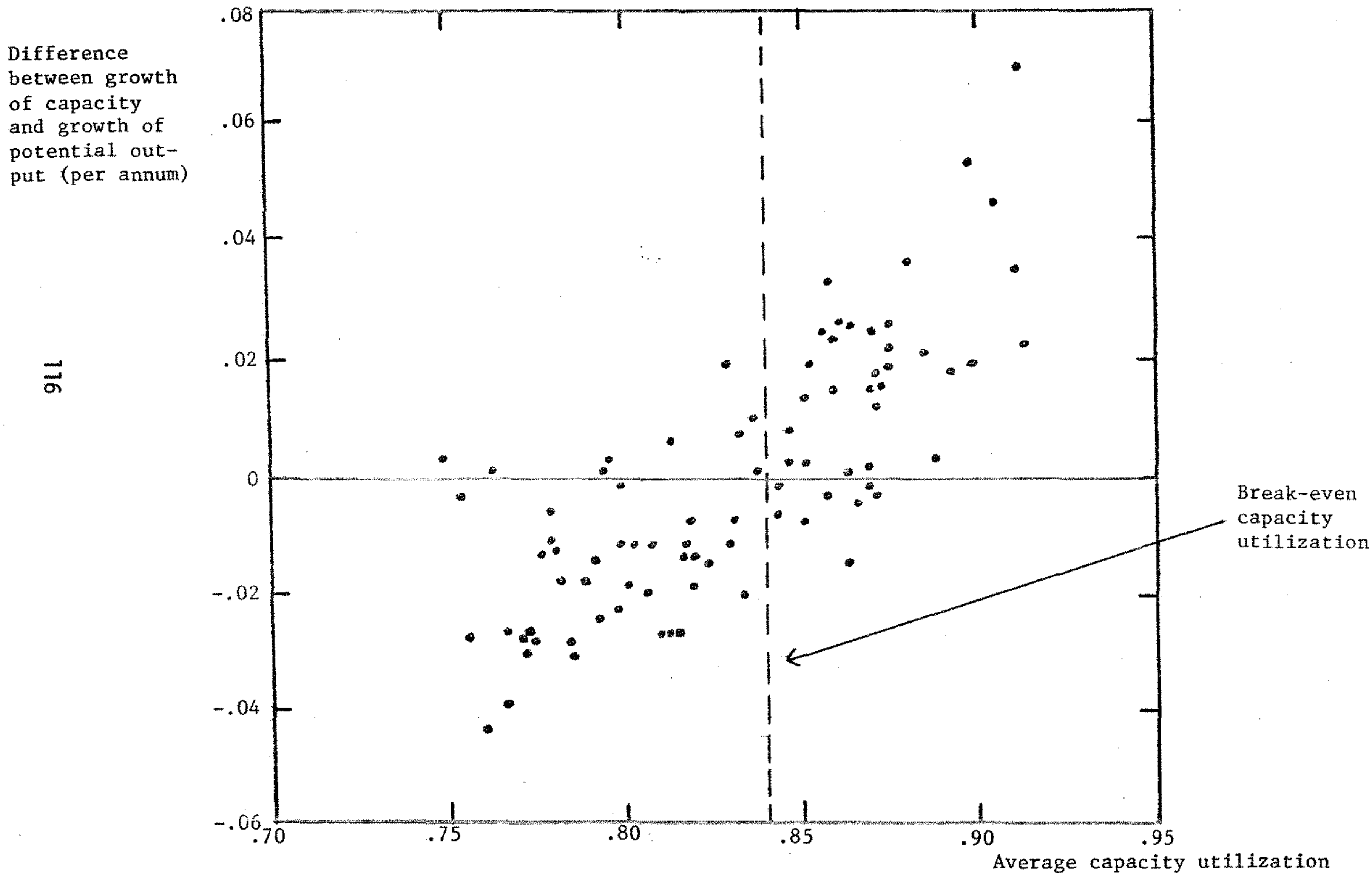

Figure 2. Relationship between lagged average capacity utilization and the growth of capacity relative to potential output, 1955-76. The level of capacity at which capacity and potential output grow at the same rate ("break-even capacity utilization") is estimated to be 84 percent.

incentives to invest are insufficient to keep the capital stock growing as rapidly as potential output.

It appears that even today we are below the break-even point, for over the last few months capacity utilization in manufacturing has been averaging only 83 percent.

To summarize the evidence up to date: we are faced with a paradoxical situation. Capacity output has been growing more slowly than potential output for some time now. Yet, we are constrained from having a rapid growth in actual output because of the fears in many quarters of getting too close to the inflationary shoals. On the other hand, if we stay too far away from our objective of high levels of employment and utilization, we see that capacity will grow too slowly for us to reach our ultimate target. Thus, again according to historical relationships, if we were to stay at a utilization rate of 83 percent for an extended period of time, our full employment capacity utilization index would continue to rise.

Speed Limits to Growth?

We have seen that there is a fundamental dilemma which the economy faces over the next four years. A path of immediate recovery will clearly lead the economy onto the shoals of capacity bottlenecks. On the other hand, a path of very slow growth, with capacity utilization below the break-even point, will lead to an increasing secular divergence between potential output and capacity output. Clearly the optimum lies somewhere in between.

The problem is what I will somewhat whimsically call the flypaper problem. A hungry fly sees a delicious morsel of fly food across the room, but unfortunately the morsel is very close to a sticky piece of flypaper. The fly wishes to get as much of his tasty dinner as he can, but in doing so he risks the danger of overshooting his dinner and getting stuck on the flypaper.

Of course the flypaper problem is exactly the problem we have been discussing up to now. If we stay too far away from potential output and capacity in the hopes of avoiding the inflationary shoals, we will indeed not risk present inflation, but we are risking future inflation by building insufficient capacity to prevent future bottlenecks. On the other hand, if we pursue the strategy of immediate recovery, we risk encountering inflationary bottlenecks immediately, if we encounter exogenous disturbances which lead us to overshoot capacity and trigger inflation. Therefore, like our friendly fly, we must get close enough to capacity to get investment, output, and employment high, but at the same time not overshoot our target.

Strategies for The Recovery

Given our current economic situation -- high levels of unemployment and the high level of the full employment capacity utilization rate -- this suggests a strategy for the recovery must take into account both factors.

- We must assure producers that they will have adequate markets to sell their output. This implies that the levels of capacity utilization must be above the break-even point -- and soon.

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- We must assure producers that they will have adequate markets to sell their output. This implies that the levels of capacity utilization must be above the break-even point -- and soon.

- At the same time we must recognize that our labor and pro-

- duct markets are badly out of balance. This means that our recovery must proceed in an orderly fashion as investment accelerates and capacity output recovers its growth.

- The imbalance between capacity and potential output must be taken into account in our overall fiscal and monetary policy. It would be extremely untimely for the monetary authorities to slam on the brakes at that point when we so badly need investment. And our fiscal and tax policy must recognize the central importance of special incentives to invest during the next few years.

This last consideration is the one on which I would like to close. As I have indicated today, our capacity output does not dovetail with the social and economic needs of today. In designing the major fiscal policy actions over the next two years, we must taken into account the needs for capacity expansion. The Administration is considering carefully the possibility of giving special incentives for investment in the short-run to aid the growth of capacity.

It should be emphasized that -- while it is always nice to have additional capacity -- the needs over the next few years are particularly critical. If we are to succeed in reaching a noninflationary full employment economy, we must assure that capacity expansion proceeds at a sufficient pace. I expect that the Administration will propose tax measures especially designed to encourage the growth of capacity over the next few years. We hope that a climate of cooperation from the monetary authorities and the business community will make sure that, in fact, capacity bottlenecks do not slow the current recovery.

Footnote

1/ Note that the calculation is a "straight up" increase in output and utilization, like that customarily employed in calculating the "gap."

SHORT TERM PROJECTIONS OF MANUFACTURING CAPACITY UTILIZATION

James F. Ragan, Jr.

As the papers presented at this conference demonstrate, there is a divergence of views as to whether current measures of capacity utilization overstate or understate the amount of untapped capacity remaining in the economy. I want to sidestep this issue, concentrating instead on one widely used measure of capacity utilization: the Federal Reserve Board's capacity utilization rate for manufacturing. In particular, I want to discuss a simple model which can be used to project manufacturing capacity utilization, as published by the Board, over the next couple of years. Those, including certain members of the Federal Reserve Bank of St. Louis, who feel the Board's measure of capacity utilization is biased downward may argue that capacity problems will develop sooner than our model predicts; those who feel current measures of capacity utilization are biased upward may take the opposite view, arguing that capacity problems will not emerge until later. Nonetheless, examining when capacity is likely to become strained--at least on the basis of the Board's capacity utilization statistic--is an interesting experiment and provides a useful benchmark for discussions about prospective capacity problems. Indeed, to leak

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one of our findings, it is not necessary to take the "St. Louis Fed's" position that currently published measures of capacity utilization are artificially low to show their concern about potential capacity problems within the next couple of years.

The model presented in this paper is for the key sector of manufacturing, although the technique can be applied to other sectors of the economy as well. First, an equation is estimated linking growth in manufacturing output to growth in GNP. Next, additions to manufacturing capacity are estimated, based on projections of investment. The forecast of output is then divided by the forecast of capacity to yield projections of capacity utilization. The model is first used to project capacity utilization from 1977 III - 1978 IV, based on a "consensus" forecast of GNP growth. Next, implications are drawn concerning the impact on capacity utilization of strong protracted economic growth, the Administration's assumption.

Specifying the Model

Manufacturing output and GNP tend to move together. In growth terms, the relationship between these two variables can be specified as:[1/]

$$I\overset{o}{P}_t = a_o + a_1 \overset{o}{GNP}_t + \varepsilon_t \qquad (1)$$

$I\overset{o}{P}_t$ = Percentage change in the manufacturing index of industrial production, i.e., $100\ (IP_t - IP_{t-1})\ /\ IP_{t-1}$.

$\overset{o}{GNP}_t$ = Percentage change in constant-dollar gross national product.

ε_t = Error term.

The change in capacity from one period to the next depends positively on the volume of investment and negatively on the extent of depreciation, which in turn depends on the level of capacity last period. (See Appendix 1 for greater elaboration.) The change-in-capacity equation can therefore be depicted as follows:

$$C_t - C_{t-1} = b_1 C_{t-1} + b_2 I_t + \varepsilon_t' \qquad (2)$$

C_t = Capacity index for manufacturing.

I_t = Real manufacturing investment net of pollution control expenditures.

ε_t' = Error term.

As many economists have observed, investment accelerates as the volume of unused capacity shrinks, i.e., as the capacity utilization rate (CU) rises. Changes in investment are therefore specified to be a function of past changes in capacity utilization:

$$\overset{o}{I}_t = c_o \; c_1 \; C^oU_{t-1} + \varepsilon_t'' \qquad (3)$$

$\overset{o}{I}_t$ = Percentage change in investment (I) from the previous calendar year.

C^oU_{t-1} = Percentage change in capacity utilization (CU) over the previous year (fourth quarter to fourth quarter).

ε_t'' = Error term.

Although this equation greatly abstracts from the underlying determinants of investment, it performs well empirically. Another advantage of this specification is that the capacity utilization rates generated by our model can be used to project investment in subsequent years. That is, when combined with GNP projections, equations (1), (2), and (3) constitute a closed system capable of projecting capacity utilization rates indefinitely into the future.

Empirical Results

Equations (1) - (3) were estimated over the period 1954-1976. Results are reported in Table 1. From the first equation, it is apparent that manufacturing output is more volatile than GNP; the large coefficient for $\overset{o}{GNP}$ indicates that rapid GNP growth is on average accompanied by even more rapid growth in manufacturing output. The coefficient of C_{t-1} in equation (2) indicates that, in the absence of investment, capacity declines 3.35 percent per year, the result of depreciation and obsolescence. The coefficient of I_t indicates that each one billion dollars of non-pollution-control investment expenditures, measured in 1972 dollars, increases the capacity index (1976 IV = 163.2) by 0.29 percentage point. Converting the investment coefficient to an elasticity, each 1.0 percent change in real investment net of pollution control is on average associated with a 1.0 percent change in gross additions to capacity (as opposed to net additions, i.e., additions net of depreciation.)[2/] Finally, as expected, equation (3) indicates that investment accelerates as capacity utilization rises.

The fit of all three equations is quite good, as judged by the R^2 values, and all coefficients are statistically different from zero.

Table 1

Regression Results*
(t-statistics in parentheses)

$$I^{o}P_t = -.756 + 2.203 \overset{o}{GNP}_t \qquad (1)$$
$$\quad (4.22) \quad (16.46)$$

$R^2 = .751$ SE = 1.37 DW = 1.85
Sample Period: 1954 I - 1976 IV

$$C_t - C_{t-1} = -.0335\, C_{t-1} + .2923\, I_t \qquad (2)$$
$$\quad (3.23) \quad (7.10)$$

$R^2 = .935$ SE = .576 $\hat{\rho} = .578$ DW = 1.70
Sample Period: 1954 - 1976

$$\overset{o}{I}_t = 4.196 + 1.754\, C^{o}U_{t-1} \qquad (3)$$
$$\quad (2.97) \quad (6.55)$$

$R^2 = .671$ SE = 6.74 DW = 1.71
Sample Period: 1954 - 1976

Note: $I^{o}P$ = Quarterly growth of manufacturing output
$\overset{o}{GNP}$ = Quarterly growth of real gross national product
C = Index of manufacturing capacity
I = Real manufacturing investment net of pollution control expenditures
$C^{o}U$ = Growth of capacity utilization in manufacturing

* The Cochrane-Orcutt iterative technique was used to adjust for first-order autocorrelation in equation (2).

Even more important, simulation results (presented in Appendix 2) indicate that the model does a good job of tracking capacity utilization during the current recovery. Having passed this test, the model was then used to run two experiments, described in the following sections.

Projecting Capacity Utilization, 1977 III - 1978 IV

Based on the increase in investment projected for 1977 -- $\overset{o}{I}_{77}$ = 12.9 percent[3/] -- capacity is projected to increase by 3.2 percent between 1976 IV and 1977 IV. The increase is assumed to be distributed equally throughout the year, implying a quarterly growth in capacity of 9.791 percent.[4/] Output growth is projected using the median of eight prominent forecasts of real GNP growth, as published in the September 1977 issue of the Conference Board's Statistical Bulletin (see Table 2). The output growth and capacity expansion projections are brought together in Table 3.[5/] Based on the Conference Board median GNP forecasts, our model projects that capacity utilization in manufacturing will increase steadily to 85.8 percent in 1978 IV. Capacity will expand at a 3.2 percent annual rate in 1977 and at a 3.9 percent rate in 1978, compared to the 2.3 percent rate of 1976; manufacturing output will increase over the forecast period at an average annual rate of 6.3 percent.

The 85.8 percent rate projected for 1978 IV is but 2 percentage points below the 1973 quarterly peak and 2.8 percentage points below the highest peacetime peak recorded. Hence, based upon the median

Table 2

Real GNP Growth,
Median Conference Board Forecast

		Compound Annual Growth Rate	Quarterly Growth Rate
1977	III	4.4 percent	1.082 percent
	IV	4.6	1.131
1978	I	4.45	1.094
	II	4.4	1.082
	III	4.2	1.034
	IV	3.4	.839

Source: The Conference Board, <u>Statistical Bulletin</u>, September 1977.

Table 3

Capacity Utilization Projections
Based on Median Conference Board Forecast

		$\overset{o}{C}$	$\overset{o}{GNP}$	$\overset{o}{I}P$	ρ	CU
1977	II					82.6
	III	.791	1.082	1.628	1.008	83.3
	IV	.791	1.131	1.736	1.009	84.0
1978	I	.961	1.094	1.654	1.007	84.6
	II	.961	1.082	1.628	1.007	85.2
	III	.961	1.034	1.522	1.006	85.7
	IV	.961	.839	1.092	1.001	85.8

Note: $\overset{o}{C}$ = Percentage change in capacity (from previous quarter)
$\overset{o}{GNP}$ = Percentage change in real GNP
$I^{o}P$ = Percentage change in manufacturing output
$\rho = (IP_t \,/\, IP_{t-1}) \,/\, (C_t \,/\, C_{t-1})$
CU = Capacity utilization (percent)

forecast of GNP growth, as published by the Conference Board, our model indicates that the manufacturing sector is likely to contain some modest amount of untapped capacity at the end of 1978, yet little enough so that concern over bottlenecks in 1979 seems warranted.

Capacity Utilization as Implied by the Administration's Projections of GNP Growth

The Administration recently set a goal of reducing the aggregate unemployment rate to 4.6 percent by the end of 1981. To achieve this goal, they estimate that real GNP must grow from 1977 through 1981 by an average of 5.1 percent per year.[6/] The implications for capacity utilization can be examined by plugging the 5.1 percent growth rate into our model -- an experiment which indicates the Administration's goal is apparently overly optimistic. Based on the Administration's GNP figures, our model projects that capacity utilization would reach its 1973 peak in 1978 IV, its peacetime peak in 1979 I, and its all-time peak in 1980 I (see Table 4). Assuming 5.1 percent GNP growth could be sustained, capacity utilization would rise to 96 percent in 1981 IV. Historical experience, however, indicates that a utilization rate this high is unattainable for manufacturing; widespread shortages and bottlenecks would emerge well before such a rate could be achieved.

Of course, investment is not actually predetermined through 1981. The investment values forecast by the model were based on the historical relationship between changes in capacity utilization and changes in investment growth. But investment growth can be influenced by other factors as well; e.g., by changes in tax policy or in the degree of uncertainty facing businessmen. Therefore, if the Administration wants to foster prolonged economic growth it must attach increased importance to stimulating investment, thereby slowing the rise in capacity utilization and postponing the time when capacity will become strained. Yet, even if investment is spurred the Administration's goal may still prove elusive. Our model suggests that, on the basis of continued strong GNP growth, capacity problems are likely to appear within the next two years.

Table 4

Capacity Utilization Projections
Based on the Administration's GNP Scenario

		$\overset{\circ}{C}$	$\overset{\circ}{GNP}$	$\overset{\circ}{I\ P}$	ρ	CU
1977	II					82.6
	III	.791	1.251	2.000	1.012	83.6
	IV	.791	1.251	2.000	1.012	84.6
1978	I	.985	1.251	2.000	1.010	85.4
	II	.985	1.251	2.000	1.010	86.3
	III	.985	1.251	2.000	1.010	87.2
	IV	.985	1.251	2.000	1.010	88.0
1979	I	1.131	1.251	2.000	1.009	88.8
	II	1.131	1.251	2.000	1.009	89.6
	III	1.131	1.251	2.000	1.009	90.4
	IV	1.131	1.251	2.000	1.009	91.2
1980	I	1.251	1.251	2.000	1.007	91.8
	II	1.251	1.251	2.000	1.007	92.5
	III	1.251	1.251	2.000	1.007	93.1
	IV	1.251	1.251	2.000	1.007	93.8
1981	I	1.348	1.251	2.000	1.006	94.4
	II	1.348	1.251	2.000	1.006	94.9
	III	1.348	1.251	2.000	1.006	95.5
	IV	1.348	1.251	2.000	1.006	96.1

Appendix 1: Projecting Capacity Growth

Additions to manufacturing capacity are estimated from investment data. Investment is measured in real or constant-dollar terms, since capacity is related to real rather than nominal investment. In addition, pollution control expenditures are netted out, since these expenditures do not augment productive capacity. Yet, even with these adjustments, translating investment data into capacity growth can be tricky.

One difficulty is that the composition as well as volume of investment is important. Investment which eliminates a production bottleneck may have a tremendous impact on capacity. On the other hand, investment which expands plant size may, while providing additional office space, leave plant capacity unchanged. A new machine, if added to the existing stock of equipment increases capacity, but if some existing equipment is retired when the new machine is put in place capacity need not be increased. Furthermore, expenditures on modernization generally provide for smaller capacity growth than outlays on new plant and equipment. Finally, the impact of an investment dollar is likely to vary from industry to industry. A dollar spent in an industry approaching capacity will have a more pronounced impact on aggregate capacity than a dollar spent in an industry possessing abundant unused capacity.

Also complicating the investment-capacity relationship is the fact that investment frequently increases capacity with a lag. Projects requiring years to finish are likely to add to capacity only when completed or nearly so. A plant half-completed may not augment a firm's capacity at all. Moreover, the lags involved may vary both over time and by type of investment.

The severity of these problems is difficult to assess *a priori*. While the composition of investment may vary substantially over time for a particular company or industry, in the aggregate the composition of investment may remain relatively stable. Therefore, how well aggregate investment explains capacity growth is ultimately an empirical question. So is the question of whether capacity growth this period is significantly related to previous investment. Each period, investment dollars are spent which increase capacity only in the future. At the same time, however, certain projects started in the past are finished, adding to capacity in the current period. If these two lag effects wash out sufficiently, then empirically capacity growth may not be related to previous investment, but only to current investment. To investigate the relationship between investment and capacity, the following model was developed.

Capacity in a given period (C_t) is identically equal to capacity last period minus the loss in capacity due to depreciation and obsolescence (D_t) plus the gross additions to capacity ($CADD_t$), i.e.,

$$C_t \equiv C_{t-1} - D_t + CADD_t. \quad (4)$$

It is assumed that capacity depreciates at a constant rate each period:

$$D_t = \alpha C_{t-1}. \quad (5)$$

In addition, it is assumed that gross additions to capacity are related to current and possibly previous investment:

$$CADD_t = \beta_1 I_t + \beta_2 I_{t-1} + \ldots \quad (6)$$

where I_t refers to real investment net of pollution control expenditures.

Combining the above equations, capacity can be rewritten as:

$$C_t - (1-\alpha)C_{t-1} + \beta_1 I_t + \beta_2 I_{t-1} + \ldots \varepsilon_t. \quad (7)$$

where ε represents the error term. Alternatively, the change in capacity can be expressed as:

$$C_t - C_{t-1} = -\alpha C_{t-1} + \beta_1 I_t + \beta_2 I_{t-1} + \ldots \varepsilon_t. \quad (7')$$

Estimates of α and β are the same whether obtained by estimating equation (7) or equation (7').

The capacity variable of this study refers to manufacturing capacity as measured by the Board of Governors of the Federal Reserve System.7/ Capacity values were obtained for the fourth quarter of each year (see Table 5). Fourth-quarter values were chosen because both the Board of Governors and McGraw-Hill estimate capacity growth on an end-of-year basis.

The investment variable (I) is an estimate of real plant and equipment expenditures over the calendar year net of pollution control spending. The variable is defined as follows:

$$I = PE\ (100 - POL)/P$$

where PE = Expenditures for new manufacturing plant and equipment, in billions of (current) dollars;

POL = Percent of plant and equipment expenditures for air and water pollution control;

P = Implicit GNP price deflator for business fixed investment.

The PE data are published by the Bureau of Economic Analysis, the POL data by McGraw-Hill.[8/]

Equation (7') was estimated over the period 1954-76.[9/] Lagged investment terms did not contribute to the explanatory power of the equation, nor were their coefficients statistically significant. Only current investment proved to be statistically important. Therefore, the lagged investment terms were dropped. (Regression results are reported in Table 1, equation (2).

Table 5

Values of the Investment and Capacity Variables

	Investment (I)	Capacity (C)
1953	18.9	62.7
1954	17.8	65.1
1955	18.3	67.9
1956	22.2	71.4
1957	22.7	74.2
1958	17.2	76.6
1959	17.2	79.3
1960	20.3	83.0
1961	19.4	85.9
1962	20.2	88.8
1963	21.6	92.1
1964	25.4	96.1
1965	30.4	102.7
1966	35.6	110.2
1967	35.0	117.9
1968	33.3	124.7
1969	35.1	131.1
1970	33.1	136.1
1971	28.9	140.0
1972	28.7	144.7
1973	33.2	150.3
1974	36.2	155.7
1975	33.0	159.5
1976	34.2	163.2

Appendix 2: Simulating the Model

To test its predictive ability, the model was simulated over the first nine quarters of the current recovery. The equations, estimated over the period 1954 I to 1974 IV, were used to generate forecasts for 1975 II - IV. After updating the equations through 1975 IV, forecasts for 1976 were made. Finally, after extending the sample period through 1976 IV, capacity utilization was forecast for the first two quarters of 1977.

Simulation results uncovered no apparent bias. Although capacity utilization was somewhat underpredicted during 1976, the model did get back on track. Capacity utilization was recorded to be 82.6 percent in 1977 II, compared to a projected rate of 82.7 percent (see Table 6). Thus, capacity utilization rose 11.7 percentage points during the first nine quarters of the recovery, compared to the 11.8 percentage points projected by our model. Moreover, actual capacity utilization and the rate predicted by our model never diverged by more than 1.3 percentage point. Our model even picked up the decline in capacity utilization registered in 1976 IV.

Table 6

Simulations of Capacity Utilization

		$\overset{\circ}{C}$	$\overset{\circ}{GNP}$	$\overset{\circ}{IPP}$	ρ	$\hat{CU}$	CU	$\hat{CU}$-CU
1975	I						70.9	
	II	.668	1.573	2.627	1.019	72.2	71.3	.9
	III	.668	2.735	5.008	1.043	75.4	75.3	.1
	IV	.668	.745	1.930	1.003	75.6	76.8	-1.2
1976	I	.595	2.130	3.946	1.033	78.1	79.0	-.9
	II	.595	1.234	1.965	1.014	79.2	80.2	-1.0
	III	.595	.959	1.357	1.008	79.8	80.8	-1.0
	IV	.595	.288	-.126	.993	79.3	80.6	-1.3
1977	I	.791	1.833	3.282	1.025	81.3	81.2	.1
	II	.791	1.503	2.555	1.018	82.7	82.6	.1

Note: $\hat{CU}$ = Capacity utilization as simulated by the model
CU = Actual capacity utilization

Footnotes

1/ Nonlinear versions of equation (1) were also tried, but their results were empirically inferior.

2/ The term $G_t \equiv C_t - (1-\alpha)C_{t-1} = C_t - .9665\ C_{t-1}$ measures the gross change in capacity, i.e., the difference between actual capacity and the level which would have prevailed in the absence of any investment. Since G = .2923 I, the elasticity of G with respect to I, evaluated at the mean, is $\eta = .2923\ \bar{I}\ /\ \bar{G}$ where $\bar{I}$ and $\bar{G}$ refer to the mean values of I and G over the estimation period (1954-76). $\bar{I}$ = 26.92 and G and 7.89. Hence, η = .2923 (26.92 / 7.89) = 1.0. In other words, each 1 percent change in our investment variable is associated with a 1 percent change in gross capacity growth. Therefore, if in a certain year $25 billion in investment would increase capacity by 5 percent in gross terms, then raising investment to $30 billion (an increase of 20 percent) can be expected to raise gross capacity growth to 6 percent (also an increase of 20 percent). The finding that investment changes and changes in capacity growth are linked in such a manner is appealing on theoretical grounds, and suggests that our investment variable does a good job of capturing gross additions to capacity.

3/ Interestingly, the 1977 projection of investment derived from equation (3) falls in between the investment plans reported by the BEA and by McGraw-Hill in late spring. Based on the growth in capacity utilization between 1975 IV and 1976 IV, equation (3) projects that manufacturing investment in 1977, as measured by our investment variable (I), will exceed investment in 1976 by about 12.9 percent. The BEA investment survey figures translate into a 9.3 percent increase in I; the McGraw-Hill figures, into a 14.3 percent increase (assuming a 6 percent increase in the price of investment goods (P) and using the 1977 estimate of pollution control expenditures reported by McGraw-Hill).

4/ That is, $(1.00791)^4 = 1.032$.

5/ Capacity utilization in time period t is defined as the ratio of actual output to capacity output, i.e.,

$$CU_t = IP_t/C_t.$$

By lagging this relationship one period, it can easily be shown that the utilization rates in successive periods are related as follows:

$$CU_t = \rho \, CU_{t-1}$$

$$\text{where } \rho = \frac{IP_t \,/\, IP_{t-1}}{C_t \,/\, C_{t-1}}.$$

This is the formula used to project capacity utilization.

6/ See Office of Management and Budget, Midsession Review of Fiscal 1978 Budget, Special Supplement, July 1, 1977.

7/ Among other advantages, the Board of Governors series is readily available to the general public, has a long track record, and lacks any apparent cyclical bias. For a discussion of the major series of capacity utilization, see James Ragan, "Measuring Capacity Utilization in Manufacturing," Federal Reserve Bank of New York Quarterly Review, Winter 1976, pp. 13-20.

8/ The pollution control data are actually available only since 1967; but, because pollution control expenditures did not begin their rapid ascent until the late sixties, the fraction of investment expenditures devoted to pollution control prior to 1967 was probably close to the fraction spent in 1967. This was the assumption made. Thus, the pre-1967 values of POL were set equal to the 1967 value (2.8 percent). The BEA also publishes a series on pollution control expenditures, but it does not begin until six years after the McGraw-Hill series.

9/ The estimation period was annual, rather than quarterly, because truly independent capacity values were available only once per year. Both the Federal Reserve Board (whose series is used in this study) and McGraw-Hill obtain capacity values at year-end. Although quarterly estimates are available, these are simply interpolations between annual observations.

COMMENTS ON RASCHE AND TATOM,

"THE EFFECTS OF THE NEW ENERGY REGIME...."

AND

"ENERGY RESOURCES AND POTENTIAL GNP"

Frank de Leeuw

These two studies have performed a timely service in reminding us that a major rise in natural resource costs can have a sizable negative impact on potential GNP. The purpose of this note is not to question that central proposition. Rather, it is to argue that (1) the impact on potential GNP takes place only gradually as production techniques and consumption patterns change, not all at once as these studies imply, and (2) that the ultimate impact may not be as large as the 4 or 5 percent estimated in these studies.

At the present time, the note will conclude, production techniques and consumption patterns do not seem to have altered substantially in response to higher energy prices. Potential GNP has therefore not yet declined appreciably; rather, what has happened is that a larger fraction of GNP (or claims against GNP reflected in balance-of-trade deficits) must be paid to the owners of energy resources. Potential consumption after subtracting out this fraction has been reduced, but potential production has not. It is, however, important to

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watch for signs that production techniques are beginning to respond to high energy prices and to take any such response into account in formulating economic policy.

The Rasche-Tatom Assumptions and Their Implications

The reasoning used in these studies to translate higher energy prices into reduced potential GNP can be explained in a few sentences. Since output requires labor, capital, and energy, potential output depends on available supplies of these three inputs. For labor and for capital, it is possible to measure at least approximately maximum available inputs, determined by population and expected labor force participation rates in the case of labor and by the initial capital stock, its rate of depreciation, and the expected fraction of new output devoted to fixed investment in the case of capital.

Since energy is traded internationally in huge amounts, it does not make sense to think of a fixed quantity of potential energy consumption by any one country, analogous to potential labor and potential capital. Rather, it makes sense to think of producers and consumers choosing a ratio of energy to output on the basis of relative prices, technological developments, and perhaps other influences. The higher this ratio is --the more energy-intensive production is--the more output can be produced with given amounts of labor and capital. A sizable increase in the relative price of energy should lead producers to conserve energy and consumers to shift purchases away from energy-intensive goods and services--should, in other words, reduce the ratio of energy to output. High energy prices should therefore mean that available supplies of labor and capital will not yield as much output as they would have if the cheap-energy years of the past had continued.

A major increase in energy prices should, in this view, cause (1) energy conservation, or a fall in energy consumption per unit of output; (2) a rise in both labor consumption per unit of output (equivalent to a fall in productivity as usually measured) and capital consumption per unit of output; and (3) a reduction in productive capacity or potential output, properly measured. The specific relationships used by Rasche and Tatom, furthermore, imply that these reactions occur at once when relative energy prices go up.

The Evidence Since 1973

Have these consequences actually taken place since the OPEC price rise of 1973-1974? The evidence is, at best, mixed. The first consequence, a fall in the energy-output ratio, is a central one. Only as this ratio falls do producers need to use more capital and/or labor per unit of output and hence reduce potential GNP. But there is no evidence of a drop below trend in the energy-output ratio since 1973. Table 1 shows two measures of energy per unit of output from 1970 through 1976. They both display a trend toward conservation over these years amounting to a reduction of 1 to 3 percent in energy per unit of output each year. But they show this trend before the dramatic increase in energy prices as well as afterwards and there is no sign of any acceleration after the energy price increase took place. Examination of a longer period than 1970-1976 suggests that some movement toward conservation may have taken place in recent years, but nothing like the 33 percent drop in the ratio

TABLE 1

ENERGY CONSUMPTION AND GNP

(CONSTANT DOLLARS)

	Energy Consumption (thousand trillion BTUs)		GNP, 1972 Prices (billions of dollars)		Ratio of Energy to Output (indexes, 1973 = 100)	
	Total	Industrial	Total	"Industrial"1/	Total	Industrial
1970	68.3	23.3	1075.3	370.2	104.5	107.8
1971	69.5	23.0	1107.5	374.9	103.2	105.1
1972	73.3	23.8	1171.1	399.7	102.9	102.0
1973	75.1	24.9	1235.0	426.4	100.0	100.0
1974	73.2	24.2	1217.8	402.6	98.8	102.9
1975	71.5	21.6	1202.1	379.9	97.8	97.4
1976 est.	75.0	22.9	1274.7	416.2	96.8	94.2

Source: Energy Consumption--FEA, by telephone, through 1975-1976, CBO estimates based on data in FEA's Monthly Energy Review

GNP--Commerce Department

Rasche and Tatom would expect in response to the roughly 50 percent increase in the relative price of energy in 1973-1974.

With respect to labor and capital, the evidence is not quite so negative. Output per unit of labor did fall in 1974 and has not yet caught up to its earlier trend, even after correction for cyclical influences. After cyclical correction, however, output per unit of capital does not appear to have fallen. Output per unit of combined labor-capital did fall, and the Rasche-Tatom regression results reflect the fact that this shift in the relation of output to labor and capital inputs occurred at the same time as the rise in oil prices. But it is hard to interpret these labor and capital changes as responses to energy developments when there is no evidence of a shift in the energy-output ratio.

Preferred Rates of Capacity Utilization

The third implication of a rise in relative energy prices is a decline in capacity and potential GNP. As Rasche and Tatom point out, manufacturing capacity as measured by the Federal Reserve Board did not fall when energy prices went up. Capacity, as Rasche and Tatom define it--namely, the cost-minimizing or profit-maximizing level of output--should have fallen by 4 or 5 percent, according to their calculations. They interpret the failure of the actual indexes to fall as due to a difference in definition. Published capacity statistics, they believe, refer to maximum output feasible under customary operating conditions, not to the concept of cost-minimizing output which they prefer.

I believe they are probably right in their interpretation of published capacity statistics. In the short run at least, the failure of published capacity indexes to fall is not a serious argument against their view of the impact of energy prices. Neither, however, is it a confirmation of their view. It is simply not relevant to evaluating their hypotheses.

The Bureau of Economic Analysis does, however, collect another set of statistics in its capacity survey which are more relevant to testing the Rasche-Tatom views. These are manufacturers' views of the percent of capacity at which they would prefer to operate. The exact question is: "At what percentage of manufacturing capacity would your company have preferred to operate in order to achieve maximum profits or other objectives?"2/ Now if high energy prices do not change rated capacity but do have an immediate impact on production techniques and input proportions as Rasche and Tatom maintain, then the minimum-average-cost rate of operation should decline when energy becomes much more expensive.3/ A reduction in preferred operating rates looks like a promising candidate for an empirical counterpart to this theoretical concept. Manufacturers might be expected to prefer not to operate equipment which was extremely energy-intensive, and to prefer to operate other equipment in ways which conserve energy and hence sacrifice some output.

In fact, however, nothing much has happened to manufacturers' view of their preferred rate of operation. For all manufacturers taken together, preferred utilization was 95 percent of rated capacity from 1970 through 1974 and 94 percent in 1975 and 1976. There is no sign of a 4 to 5 percent drop after the run-up of energy prices in 1973-1974.

Unpublished detail supplied by the Bureau of Economic Analysis, furthermore, does not suggest that the aggregate conceals any shifts at industry levels that would bear out the Rasche-Tatom view. For example, there does not appear to have been a drop in preferred rates in energy-intensive industries offset by a rise elsewhere. Thus, statistics on preferred operating rates, like statistics on energy per unit of output, suggest that so far there has not yet been a significant restructuring of production techniques in response to higher energy prices.

What Has Been Happening?

There is no doubt that higher energy prices have created incentives to change production processes. So far, however, the evidence indicates that these incentives have not yet led to significant energy conservation and substitution of labor and/or capital for energy. Probably one reason for the delay is that many of the possibilities for energy conservation require new plant and equipment. Frequently it will pay to continue to operate existing capital goods for a time even if they utilize uneconomic processes because they have already been paid for and because conversion to a more energy-conserving process is extremely costly. Another possibility is that large-scale energy conservation is awaiting more certainty about future technological change. and about government actions affecting energy costs.

While it is tempting to associate the recent productivity slowdown with the rise in energy prices, the facts about energy per unit of output do not bear out this connection. The most likely explanation for the productivity slowdown appears to lie elsewhere--lower rates of capital investment in relation to GNP, shifts in the experience-mix of the labor force and the industry-mix of output, lower growth in research and development spending, and the severity of the 1974-1975 recession.

With respect to potential GNP, the short run conclusion is that until production techniques begin to react significantly to the change in energy prices, it would be a mistake to translate higher energy prices into reduced potential and lower output targets. So far, high energy prices have not altered production techniques but have caused this country to pay sizable amounts to oil producers in order to produce GNP by old production techniques. In paying for oil, we have incurred large balance-of-trade deficits which represent growing foreign claims against domestic output. While potential output has not yet been reduced substantially, these foreign claims mean that potential consumption by U.S. citizens has been reduced by high energy prices.

The conclusion about potential GNP in the long-run is more conjectural. Eventually high energy prices should lead to energy conservation, substitution of other inputs for energy, and hence less potential GNP from given supplies of labor and capital. Qualitatively, the Rasche-Tatom results seem quite plausible as a long-run proposition.

I suspect, however, that quantitatively the long-run effect may not be as large as 4 or 5 percent. The 4 to 5 percent estimate assumes no response of labor or technology to changing productivity and real income. In actuality, low real wages due to high fuel costs could cause the supply of secondary workers or other dimensions of labor supply to increase. Recent labor market statistics and analyses seem to be consistent with behavior of this kind, in which lower productivity is partly offset (as it affects potential GNP) by higher labor force participation. Furthermore, future technological advances could on balance be energy-saving rather than neutral (as Rasche and Tatom assume) with respect to input proportions.

These offsets are no more than possibilities, however. It would be a mistake to ignore the danger of a substantial eventual impact of high energy prices on potential GNP. The Rasche and Tatom studies will have served a highly useful purpose if they remind us to monitor closely trends in energy conservation and productivity and be prepared to adjust our estimates of potential GNP when U.S. production techniques show signs of significant reaction to the new energy regime.

Footnotes

1/ "Industrial" sector covers manufacturing, mining, agriculture, and construction for comparability with energy consumption data.

2/ See Marie P. Hertzberg, Alfred I. Jacobs, and Jon E. Trerathan, "The Utilization of Manufacturing Capacity, 1965-73," Survey of Current Business, July 1974, p. 49.

3/ Rasche and Tatom, "The Effects of the New Energy Regime," pp. 3-4.

ISSUES CONCERNING THE DEFINITION, MEASUREMENT AND FORECASTING OF PRODUCTIVE CAPACITY

Laurence H. Meyer

It would be difficult to identify a more important macroeconomic issue (and one about which there was more disagreement) than recent developments affecting the level and rate of growth in the nation's productive capacity. Knowledge of the gap between actual and potential output is of immediate relevance to the design of short-run stabilization policy and recent projections of slower growth in productive capacity and the possible relation to slower growth in capital stock appear to have heightened the interest of both the Administration and Congress in tax reform keyed to expanding incentives for capital spending. The Perry, Clark, and Rasche-Tatom papers are attempts to provide the empirical evidence on the level and anticipated rate of growth of potential output that is essential to designing such policies. However, their approaches leave the question of the level of potential output quite unsettled and their projections of future growth rates are mostly conjectural.

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Three Issues Concerning the Definition, Measurement, and Forecasting of Potential Output

It is useful to identify at the outset three separate issues concerning the definition, measurement, and forecasting of productive capacity. Each of the three papers deals at least to some extent with each of the three issues:

1. The determinants of the level of potential output.

2. The cyclical behavior of actual relative to potential output--i.e. the analysis of the cyclical pattern of participation rates, hours per worker, and productivity which along with cyclical pattern in employment explain the cyclical pattern in production.

3. The determination of the rate of growth of potential output in the past and the projection of rates of growth over the next five years.

The papers are most concerned with the level and rate of growth issues.

The Level of Potential Output

There are three problems relating to the determination of the level of potential output that arise in connection with the three papers.

a. The first problem is identifying 'potential" levels of factor inputs. Employment, hours, and participation rates vary with unemployment rates. To define the potential level of fator input, we need to know the "full employment" level of the unemployment rate. If capital is explicitly treated in the analysis, we must also define a potential level of capital input.

b. The second problem is the possibility of a once and for all shift in the level of productive capacity in 1973-5 due, for example, to a once and for all change in the relative price of energy. This must be picked up by dummy variables unless energy developments are explicitly integrated into the model.

c. The third problem is the possibility of incompatibility between potential levels of labor and capital inputs; i.e., the possibility that full utilization of the capital stock may occur prior to full utilization of the labor force and that the capital stock, not the labor force, is the real binding constraint that determines potential output. This view seemed to be prevalent in much of the recent discussions of capital shortage. It seems to me that such an incompatibility can arise only under the assumption of a putty-clay technology, but the Clark and Rasche-Tatom papers identify separate and conceivably conflicting measures of potential labor and capital inputs in a putty-putty model.

Projecting Rates of Growth of Potential Output

The second issue--the cyclical behavior of actual relative to potential output, while interesting in its own right and the issue that motivated early research in this area, is most important in the three papers as part of the methodology for providing evidence on the third issue, the trend rate of growth in potential output. The basic approach used to isolate the secular trend in the rate of growth of potential output is to purge the actual data of cyclical influences and then to fit a time trend (with appropriate dummies) to determine ex post rates of growth. When time trend dummies play such a critical role, projections of future growth rates become treacherous. Should we assume the time trend relevant to the next five years will be the same as that over the most recent homogenous period, revert to that of a still earlier period, or be different from either? Plausible stories can be told to rationalize each possible choice but the econometric evidence in the papers often doesn't help in making the choice.

Specific Comments on the Three Papers

The Clark, Rasche-Tatom and Perry papers are closely interrelated. The Clark paper, for example, follows the approach Perry employed in earlier papers to measure potential output, except that Clark introduces capital explicitly and therefore investigates weighted factor input productivity rather than labor productivity. And the Rasche-Tatom paper introduces energy as well as capital as an explicit factor input in the analysis. Finally Perry discusses the role of capital and energy in the measurement of potential output and concludes his simpler method remains capable of a more reliable estimate of potential output.

The Clark and Perry Papers

The Clark paper provides evidence that the level of potential output, if appropriately set in relation to a 4% aggregate unemployment rate in 1955, now should be defined in relation to a 4.9% unemployment rate, considers some possible explanations of the unexpectedly poor performance of productivity in 1973-4, and provides a range of estimates of the growth of potential output that reflects the inability to isolate the source of the unusual behavior of productivity in 1974. Perry simply excludes 1974 and reports small residuals in 1973, 1975 and 1976. Clark tries alternate dummies which involve a downward shift in potential output in 1974 and a more intense cyclical pattern of productivity in the 1974-5 recession. Clark is unable to choose between the two explanations (although they have very different implications for the current level of potential output) and the evidence presented in the Clark and Perry papers does not permit a definitive evaluation of Clark's dummies relative to Perry's dummy! The approach used in both the Perry and Clark papers suffers from inadequate attention to the selection of potential levels of labor input and provides little solid evidence on which to base projections of future growth rates.

1. <u>The full employment unemployment rate</u>. When the CEA designated 4% as the target unemployment rate in 1962, they rationalized the choice in terms of a simple (nonexpectational) Phillips Curve trade-off model. The trade-off model doesn't yield a unique choice for the full employment-unemployment rate (U_f) but if we assume that model is valid, it at least represents a well defined methodology for selecting U_f. Since that time, there has been a great deal of additional theoretical and empirical research on the relation between inflation and unemployment, including the development of the natural rate model. This research raised the possibility of a vertical Phillips Curve and an (in principle) well defined natural, or if not so natural, at least unique noninflationary (or nonaccelerating) rate of unemployment. Yet studies like Clark, Rasche-Tatom and Perry's continue to key the full employment level of labor input to the 4% unemployment rate in 1955 and then to translate this via changing demographic composition of the labor force to a 4.9% rate in the 1970's. Clark and Perry tell us that this unemployment rate series represents a constant degree of labor market tightness, but does not bear a direct relation to the noninflationary rate of unemployment and is not the outcome of a study of inflation dynamics. If their potential unemployment rate should not be confused with the noninflationary rate of unemployment, should their measure of productive capacity be confused with the traditional concept of potential output? Until a more serious effort is made to introduce a meaningful concept of potential labor input, the level of potential output estimated by such studies must be

treated with skepticism. Having identified their potential level of labor input with a constant degree of labor market tightness, these studies may still be able to yield meaningful insights about cyclical behavior of output relative to employment (e.g. as in Okun's Law) and the trend rate of growth in output, but the level of potential output remains arbitrary as long as there is no rationale (aside from historical continuity) for the specific constant degree of labor market tightness employed in the analysis.

2. Explaining and forecasting growth rates of potential output. The methodology used to determine growth rates of potential output is to purge the data on actual output of its cyclical component (by relating participation rates, hours per worker and productivity to cyclical variables) and then to extract the secular trend via estimation of a time trend. Ex post, this method seems capable of reasonably determining historic trend rates of growth of output. However, changes in the trend rate of growth can only be observed ex post and corrected for by time trend dummies. And projections of future growth rates involve extrapolation of recent historic growth rates plus conjectures about whether recent rates are likely to continue, the recent slowdown will worsen, or future rates will rebound. There is typically little direct support for such conjectures in the econometric analyses themselves.

3. The explicit treatment of capital stock data in projections of potential output. What differentiates Clark's paper from earlier studies and from Perry's paper is Clark's explicit treatment of the capital stock as an input rather than capturing its influence via time trends in the labor productivity equation. My initial reaction was that this was a

reasonable extension, although the whole history of debate over the baffling problem of developing a meaningful measure of the aggregate capital stock made me a bit wary. My initial favorable reaction was quickly cooled by the arbitrary way in which capital was included--by imposing fixed weights on labor and capital to form an index of total factor inputs. Perry's discussion of the difficulty in obtaining statistically significant coefficients on capital in aggregate production functions both provides a rationale for Clark's procedure and reinforces my distrust of the imposition of the arbitrary weights and my concern that problems of measuring capital may indeed make Perry's approach more reliable. Clark's defense of his treatment of capital seems to be that it does not make a great deal of difference so that using labor input and labor productivity would not have altered his results. I don't know whether this is a defense for using or not using capital!

The Rasche-Tatom Paper

The Rasche-Tatom paper employs a methodology which allows for explicit treatment of one of the alleged villains in the mystery--the influence of the sharp rise in the relative price of energy since 1973. By including the relative price of energy to proxy the input of energy in production, Rasche and Tatom find that they can explain recent developments through 1975 without resort to special dummies for the 1973-5 period. Their results also suggest a lower level of potential output in recent years even without any allowance for such factors as the increasing proportion of capital spending devoted to pollution abatement and the slowdown in the trend rate of growth in productivity after 1967 or 1969.

An increase in the relative price of energy should induce substitution out of energy into labor and capital thus increasing the labor and capital requirements per unit of output and decreasing the energy requirements per unit of output. Both Perry and Clark accept this as a plausible response to a change in the relative price of energy but attempt to capture it in their productivity equations with either dummies for a given year or time trend dummies. The issue then is the magnitude of this effect on the level of potential output and the duration of its effect on growth rates. Given the fixed levels of potential labor and capital inputs at the point of change in the relative price of energy, the increase in capital and labor requirements per unit of output translates into a decline in potential output. The greater the substitutability of capital and labor for energy, the greater the resulting decline in potential output.

This procedure raises a number of questions:

1. The results can be heavily influenced by the form of the production function and the constraints imposed in estimating the coefficients. How did the Cobb Douglas form and restrictions imposed on the parameters influence the sensitivity of potential output to the change in the relative price of energy? I share Perry's view that the Rasche-Tatom methodology has led to a serious overestimate of the resulting decline in potential output. Yet I do not find their general approach, that of including the relative price of energy as a proxy for energy input, unreasonable. Additional research with less restrictive assumptions about the production function would be useful.

2. No allowance is made for an influence of the relative price

of energy on either the "potential" level of capacity utilization or the rate of obsolescence. Both factors are treated as technical constants rather than choice variables subject to influence by changes in relative prices. Yet one of the most important channels through which the sharp increase in the relative price of energy might be expected to operate is by affecting the optimal rate of replacement investment. The theory or nontheory of replacement investment is an important gap in our conventional macro treatment of investment.

In contrast to the Rasche-Tatom paper, a 1975 paper by Myers and Nakamura[1/] on the effects of energy on productivity explicitly models the influence of a rise in energy prices on the optimal rate of replacement. They use a "vintage" (putty clay) model, and their vintage production function includes energy along with labor and capital. An increase in the price of energy is shown to effect the condition which determines the shutdown point for a given vintage. Increased energy prices result in an accelerated obsolescence of existing plant and equipment; the increase in the rate at which old vintages are replaced with new (higher technology) vintages tends to increase labor productivity. On the other hand, the increased energy prices induce a substitution to labor and capital from energy so that the amount of labor and investment required per unit of output tends to increase, reducing labor productivity. The net result on productivity is ambiguous and therefore must be determined empirically. Thus the effect of energy on productivity may be more complicated than the Rasche-Tatom analysis suggests.

3. Another questionable feature of the Rasche-Tatom analysis is the failure to allow for a gradual response of production decisions to changes in the relative price of energy. The discussion of their projections of future growth rates, on the other hand, makes reference to a gradual response to energy developments. This seems to involve conjectures quite unrelated to the explicit econometric analysis of the paper.

Summing Up

Of the three issues we identified at the outset--the level issue, the cyclical issue, and the rate of growth issue--the papers do the best job on the cyclical issue. But the main focus of the papers is on the level and rate of growth issues and their approaches to these issues have serious shortcomings. The level issue is simply unanswered due to failure to identify an appropriate potential level of labor input. In addition, the effect of the increase in the relative price of energy on the level of potential output remains unsettled. Rasche and Tatom have probably overstated the effect, but Clark's results also suggest the possibility of a substantial once and for all decline in potential output. As for the projection of future growth rates in three papers, at least in this case, time will permit us to judge whose conjectures were most accurate.

Footnotes

1/ J. G. Myers and L. Nakamura, "Energy and Pollution Effects on Productivity: A Putty Clay Approach," National Bureau of Economic Research (mimeo), 1976.

U.S. PRODUCTIVE CAPACITY: A COMMENT

Pham Chi Thanh

I find myself in a somewhat unenviable position. The three papers you heard this morning represent three different approaches to the measurement of U.S. productive capacity. The three conclusions that emerged differ quite significantly from one another--almost to the point of being contradictory. It is virtually an impossible task as a discussant, therefore, to be nice to all of the authors since if one agrees with one, one will probably have to disagree with another. The easiest way out perhaps is to play the role of a Devil's Advocate to all three papers, and so I will try to catch the Devil by the ideological tail first.

Although the three papers represent three different approaches, it is in the conclusions and their ideological implications that they differ sharply. George Perry is obviously a liberal Keynesian who shows his concern about the high level of unemployment. To say that there is a large gap between actual output and potential output is to imply that there is room for the government to interfere. Bob Rashe and Jack Tatom are just about at the opposite pole, being conservative. When they show that actual output is only a little below potential and that it will reach its potential maybe within a year, they are trying to sell us the

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idea that no government interference is good interference. "Demand management policies are both unnecessary and inflationary," as they put it. It seems quite strange to hear such an idea expressed so seriously some fifty years after Keynes' famous lecture on "The End of Laissez Faire." Peter Clark, on the other hand, seems to have managed to put himself in the middle. I have the impression that he may be a little bit conservative at heart but, being on the staff of the President's Council of Economic Advisers, he cannot very well advocate non-interference by the government.

Having speculated about the three ideologies, it is probably fair to reveal now with whom I side, if only to indicate the line of critique that I am going to deploy. Coming from a radical center like American University, it would seem to be a foregone conclusion. I certainly share George Perry's concern about high unemployment and his belief that the government might be able to interfere to alleviate it, although I do not agree with his approach to the problem of measurement of potential output. From a pure theoretical point of view, Rashe and Tatom's approach is a better one, although there are a number of technical details that I found unsatisfactory. By way of substantiating these remarks, let me begin with some background first.

To relate a given level of effective demand to a unique volume of employment is one of Keynes' famous contributions to short run analysis. This is perfectly legitimate. If the period is sufficiently short, one can reasonably assume that other factors of production are fixed. After all, the structure of social capital, for example, can only change gradually. Thus Keynes believes that there exists a level of aggregate effective demand that would generate full utilization of the labor force. Keynes was aware, of course, that even in the short run full employment does not imply a zero rate of unemployment since there will always be frictional and/or voluntary unemployment. On the other hand, to relate a given rate of unemployment to a unique level of aggregate supply is Arthur Okun's contribution (now commonly referred to as Okun's Law), which led to this potential GNP debate. Okun's Law is about the long-run rather than the short-run -- at least that is how it has been used, with some confusion, in the last fifteen years or so. The general consensus seems to be that, even in the long-run, full utilization of the labor force implies a certain rate of unemployment. This is not a new belief stemming from recent revelation. Marx, for example, wrote intensively on the "reserve army of the unemployed" and, in modern times, one often hears the term the "natural" rate of unemployment from a conservative like Milton Friedman as well as from a liberal like Edmund Phelps. Indeed, no rate of unemployment in the short run can be regarded as "natural" by anyone in any sense.

Almost everyone seems to subscribe to the view that in the long run there is a minimum rate of unemployment that can not be reduced permanently by fiscal or monetary measures. This is the so-called "benchmark" unemployment rate. The obvious initial confusion was that it was measured by the simple head count, which is appropriate only in the short run. This is because unemployment, like sickness, takes its toll in all age groups and in both sexes. For some reason, certain groups like female and young males, particularly black, are more susceptible to the disease than others. It follows, therefore, if the composition of the labor force changes, the benchmark rate will change accordingly. George Perry's ingenious device of unemployment weights is well-known and addresses itself directly to the long-run measure of the benchmark rate. In this respect, Peter Clark's work on labor force and participation rates also deserves praise. The only thing that I am unhappy about is the easy and convenient reference to "cyclical variations" and "trend break." Of course, they are necessary to suit their econometrics but these do not provide an explanation. To give an example, Perry's 1967 trend break happens to coincide with a remarkable phenomenon. Beginning in about 1966, the hourly wage of unskilled and semi-skilled workers falls relatively to the hourly wages of skilled workers. This was also the beginning of a period of expansion by U.S. multinational firms. They started to move their labor-intensive processes of production abroad where unskilled and semi-skilled labor was cheaper than in the U.S. One can imagine that a great proportion of females and young males, who were new in the labor market, belonged to this unskilled and semi-skilled category. To emphasize the point more strongly, one could say that the largest 500 firms in the U.S. can provide the same level of output with significantly less manpower by moving some of their production away from the U.S. and then importing these goods back to the home market. That is why Peter Clark's exclusion of "output generated from the rest of the world," which seems perfectly reasonable and innocent on the surface, might have an important bearing on domestic output and the actual volume of employment. It would be nice to know how much of the "output generated from the rest of the world" was actually produced by U.S. multinational corporations.

Now, since all authors in their revision of the Council of Economic Advisers' early estimates of potential GNP have looked upon the benchmark unemployment rate as a long-run concept, they all naturally extend their analyses to take account of other factors of production such as capital and energy resource. Everyone knows that the presence of capital input will pose great difficulty. Even in pure theory, the capital problem has never been quite settled. When one wants to deal with it econometrically it is a real headache and I can sympathize with George Perry's complaint. Unlike non-durable goods which can be handled with the help of an index, the evaluation of capital involves not only a cross-section index but also one that involves time itself. A new airplane is as different from an old airplane as it is from a new motor car. Strictly speaking, however, the evaluation of capital is no more complicated than the evaluation of labor. Perry wonders how are we to measure the flow of the productive services from a machine since, without incurring any new investment, we can expand its productivity by extending the number of hours it is used. Well, the same applies to a worker. The flow of productive services from a worker can always be expanded by making him or her work longer hours rather than adding an extra person to the labor force.

Although Peter Clark and Rashe and Tatom recognize the difficulty, they brave a try at the capital stock. The strange thing is that they pay so much attention to obtaining a measure of the labor force and unemployment that is better than the simple head count, but did not do the same with respect to capital stock. Just as the simple head count will give a wrong picture of labor input and unemployment, counting machines will give a wrong picture of capital input. Indeed, as far as capital stock is concerned, it is very important to know the composition of social capital, and the average life of plants and capital equipment as well as the rate of accumulation. Any change in these will affect the volume of output produced, and therefore the relationship between output and labor utilization.

Knowledge of the rate of accumulation is of particular importance when energy resource is recognized as another factor of production. Even in the theoretical literature the introduction of an exhaustible resource, such as energy, into the analysis of growth is a new thing. I applaud Rashe and Tatom's effort in incorporating this into their estimate of potential output. Their use of a Cobb-Douglas production function is however unfortunate. While there are good reasons in the theoretical literature for the use of a Cobb-Douglas production function, there is no compelling reason for using it here. This particular production function is used in the theoretical literature because it is the best weapon to defend growth theory. Two of the special properties of the Cobb-Douglas production function are that (i) output falls to zero whenever one input falls to zero so that every input is essential and (ii) the Average Product and Marginal Product of every input goes to infinity as the input falls to zero. Unless we make such assumptions, there cannot be any economic growth when exhaustible resource is a factor of production if the stock of resource is finite and if its average product is unbound only a finite quantity of output can ever be produced. Therefore if growth is to be possible, this must not happen. But that is the theoretical literature, where one is at liberty to make any assumption to suit one's line of defense. For the problem at hand, the use of a Cobb-Douglas functon, besides its usual distorted picture of production, involves also the implication of infinite substitution possibility between energy and other input. If the price of one input rises relative to another, we substitute. Well, the concept of substitution at the macro level in economics is a strange one. It is like a beautiful woman, always being loved and always being misunderstood. Substitution in the macroeconomic sense does not mean input can always be immediately transformed. A drastic fall in wage rate today does not mean that each Greyhound bus from Chicago to St. Louis will now be driven by ten drivers. A drastic rise in the price of fuel does not mean that the bus will be pushed by drivers to St. Louis all the way from Chicago. Substitution in the macro sense must be understood as scrapping old equipment and replacing it with new, accompanied by a different labor intensity and/or different fuel consumption. Very high fuel cost will lead to the production of new cars which consume less gas. In other words, it takes time and needs the help of technical progress. In using a Cobb-Douglas production functon, Rashe and Tatom make the same specification error as the followers of Solow made more than a decade ago. The elasticities α, β and γ in their paper are the so-called "surrogate" elasticities. They do not tell us about the relative shares nor do they give any information about the production process. Therefore, the calculation of potential output based on such a function is quite futile. Their estimate of demand for energy is based on the assumption that energy will always be used, up to the point where the value of its marginal product is equated to its price. Beside the implication of instant substitution that I mentioned earlier, this assumption also carries another extraordinary implication. Their estimated value of the output elasticity for energy is 9.4% which implies that the share of energy factor in the U.S. national income is almost 10%!

Earlier, I said that the knowledge of the rate of saving is of particular importance when energy resource is recognized as another factor of production. If income is to grow steadily, then the rate of saving affects not only the rate of growth but also the level of output produced. Rasche and Tatom's calculation of growth rate of 3% is therefore more of a wild guess than a meaningful estimate.

In general, I think it is possible to estimate potential output, which corresponds to given levels of input utilization. But to do so, one needs to be able to estimate capital stock and energy resource utilization correctly. The three papers do not give satisfactory calculations in this respect. From a more general viewpoint, I also think the debate misses a fundamental point. Everyone obviously likes to see a lower rate of unemployment and it may be possible to reduce it to a long run minimum rate by expanding output. But this is a shortsighted view. Faster growth rate or higher production also means using up exhaustible resources at a faster rate. A wrong choice may mean drying up resources at a point in time that we cannot afford to do so. The problem is not a simple trade-off like the inflation-unemployment trade-off of the good old days of the Phillips' curve. It is more like a trade-off between low unemployment now and high unemployment later or relative abundance now and poverty later. The choice involves future generations yet to be born, and therefore, no social contract is possible. I think that unless we can address ourselves to this problem, the estimation of potential GNP or benchmark unemployment rate does not have much meaning beyond an intellectual exercise.