POTENTIAL OUTPUT:

RECENT ISSUES AND PRESENT TRENDS

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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.

<u>The Case Against High Estimates of Energy Price Impacts</u>

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

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

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

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

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

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) $$\frac{\overline{Q}}{\overline{H}} = Be^{(r_1 t_1 + r_2 t_2)} .$$

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

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

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

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.